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APPLICATIONS OF SKYLAB EREP PHOTOGRAPHS TO MAPPING LANDFORMS AND ENVIRONMENTAL GEOMORPHOLOGY IN THE GREAT PLAINS AND MIDWEST

(EREP No. 491; NASA Contract No. T-4647-B)

Roger B. Morrison (Principal Investigator)
U. S. Geological Survey

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16. Abstract. Chief objectives of this project were (1) to evaluate in detail the 1290 Skylab S190A and S190B photographs received of Illinois, Iowa, Kansas, Missouri, Nebraska, and South Dakota, in terms of coverage, cloud cover, photographic quality, endlap, detectibility of roads and stereorelief, and utility for geomorphologic mapping; and (2) to test the utility of the Skylab photos for interpretive analytic mapping of geomorphologic features over large areas representative of different parts of this region. The State Geological Surveys of these states collaborated in the study.

The chief product of objective (1) is several charts that compare in relatively quantitative terms the quality and utility of each S190A band and of the S190B photos (unenlarged and enlarged) from each SL flight over the region. The chief product of objective (2) is a series of photointerpretive maps of analytic geomorphology (scales 1:250,000 to ca. 1:956,000) of various test areas representative of the varied landscapes of this region. These maps, covering ca. 100,000 sq km, show differences in slope, local relief, terrain profile, drainage pattern, soil color, and soil drainage, as well as geologic linears. They are designed to identify geomorphic anomalies that may reflect local tectonism, old moraine remnants, ice-marginal and other drainage diversions, and filled valleys. Such information is useful for regional land-use planning, ground-water exploration, and other environmental geomorphologic-geologic applications.

Compared with Landsat-1 MSS images, Skylab photos afford almost as extensive overviews of large areas but in considerably greater detail, and for many SL photos, moderate stereorelief. However, repetitive multiseasonal, cloud-free coverage by high-quality photos is very limited and many areas have no coverage at all.

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Figure 2A. Technical Report Standard Title Page. This page provides the data elements required by DoD Form DD-1473, HEW Form OE-6000 (ERIC), and similar forms.

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1.0 SUMMARY OF PROJECT

1.1 General background and objectives[1]

The Skylab S190A and S190B photos are the first space photographs of the Great Plains and Midwest. They provide a totally new perspective for geomorphologists and geologists--relatively high resolution, comprehensive, multiseasonal, and multispectral overviews of large parts of this region. They are important new tools for rapid small- to intermediate-scale mapping of geomorphology and surficial-geologic materials, and for identifying geomorphic-geologic anomalies of various types. Most of the Great Plains-Midwest is covered by surficial deposits of Quaternary age, hence knowledge of the Quaternary geomorphology and geology is fundamental to understanding the region's environmental-geologic resources and problems.

Unfortunately, reasonably detailed geomorphologic maps are almost nonexistent, and large parts of the region also lack good maps of the surficial geology. Therefore, a key objective of this project was to test the utility of Skylab (SL) S190A and S190B photos for interpretive analytic mapping of geomorphic (landform) features over large, representative parts of this region. Special attention was given to the possibility of recognizing and mapping end moraines of the last glaciation, remnants of end moraines of earlier glaciations, terraces along main rivers, and ancient river valleys. Geomorphic interpretation was stressed rather than geologic, because landforms can be more directly interpreted from the SL photos than surficial deposits; also many study areas are without maps of surficial geology and the time available for this project did not permit any field studies.

The State Geologists of Illinois, Iowa, Kansas, Missouri, Nebraska, and South Dakota were sent copies of all Skylab photos (and also of the ultrahigh U-2 and WB-57 airphotos) that we received of their states. The State Geologists and their geological surveys were requested to comment on the utility of these photos for scientific and practical work. We also asked for comments from several states on the utility of our own geomorphologic mapping and on anomalous features discovered by this mapping. We received valuable comments from members of the geological surveys of Illinois, Kansas, Missouri, Nebraska, and South Dakota. Particularly helpful was a report by Jerry A. Lineback, of the Illinois State Geological Survey, comparing the utility of Skylab photos, ERTS-1 images, and RB57 airphotos for mapping surficial and bedrock geology in Illinois. Dr. Lineback's appraisal is included as Appendix A5 in our report.

Table 0.5 summarizes results obtained in each state, both from our work or from members of the state geological surveys.

Table 0.5--NEAR HERE

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[1]This project is an extension of a previous NASA-supported ERTS (Landsat)-1 investigation in the same 6-state region, whose objectives were similar (Morrison and Hallberg, 1975).

TABLE O.5. WORK DONE UNDER THIS PROJECT IN EACH STATE, AND CHIEF ACCOMPLISHMENTS (Page 1 of 2)

WORK DONE		SCIENTIFIC/PRACTICAL ACCOMPLISHMENTS
By Principal Investigator and/or USGS assistants	By members of the state geological survey	(1) By P.I./USGS (2) By state geological survey
ILLINOIS		
1. Indexed and mapped coverage of all SL S190A and S190B photos of Illinois. 2. Sent 1 copy of each SL photo to the State Geologist. 3. Evaluated the quality and utility (for geomorphic/geologic mapping) of all the SL photos for Illinois. 4. Determined coverage for S192 multi-spectral imagery for Illinois. 5. Sent 1 copy of the S192 MSS imagery for Illinois to the state geologist. 6. Evaluated the quality and utility of the S192 MSS imagery. 7. Mapped from S190A and S190B photos the analytic geomorphology of two areas in Illinois (1 area similar to the western half of Appendix Fig. A5.1, the other the eastern part of Appendix Figs. A2.4b and A2.5b. 8. Mapped geologic linears in detail in a small area in western Illinois (Appendix Fig. A6.1). 9. Visited the state survey and discussed results of our combined efforts.	1. Evaluated the quality and utility of SL photos for geologic mapping in Illinois. 2. Mapped surficial (mainly glacial) and bedrock geology from S190A and S190B photos in large parts of the state. 3. Prepared a report on items 1 and 2 which appears as Appendix section A6.0 here. 4. Published a report (Lineback, 1975) giving a general evaluation of the utility of SL photos for geologic mapping, compared with ERTS-1 images and U-2 airphotos. 5. Conferred in person and via correspondence and telephone on the results of our combined efforts.	1. Prepared relatively small-scale (1:475,000 to 1:713,000) geologic maps from the SL photos (2) 2. Prepared analytic geomorphologic maps at the same scales from the SL photos. (1) 3. Found a possible previously unrecognized glacial moraine of late Wisconsinan age extending southwest from Champaign toward Sullivan. (2) 4. Found a previously unknown small proglacial lake basin just south of the Shelbyville moraine near Mattoon.(2) 5. Found many semiparallel to somewhat radial linear features on the late Wisconsinan drift plain west of Champaign-Urbana. These are thought to be related to ice movement, i.e., drumlinoid.(2) 6. Found similar radial linear features on the Illinoian drift plain south and west of Galesburg. (2,1). 7. Established ability to map strip-mined areas and to determine their degree of reclamation and/or forestation, especially on S190B photos. (2, 1) 8. Determined that some but not all known faults (in bedrock) can be identified as geologic linears on SL photos. (2). 9. Determined that many sinkholes can be seen on S190B photos. (2)
IOWA		
1. Indexed and mapped coverage of all SL S190A and S190B photos of Iowa. 2. Sent 1 copy of each SL photo to the State Geologist, with request for an evaluation of their utility for scientific and practical work. 3. Evaluated the quality and utility of all SL photos of Iowa. 4. Mapped from S190A and S190B photos the analytic geomorphology of western Iowa near Omaha, Nebraska. 5. Mapped geologic linears in detail in this area.	1. Several telephone conversations with P.I., but no specific evaluations.	1. Mapped analytic geomorphology in central-western Iowa near Omaha, Nebraska (1). 2. Mapped geologic linears in the above area. (1)
KANSAS		
1. Indexed and mapped coverage of all SL photos of Kansas. 2. Sent 1 copy of each SL photo to the State Geologist, with request for evaluation of their utility for scientific and practical work. 3. Evaluated the quality and utility (for geomorphic/geologic mapping) of all the SL photos of Kansas. 4. Determined coverage of the S192 multi-spectral imagery of Kansas. 5. Sent 1 copy of the S192 MSS imagery of Kansas to the State Geologist. 6. Evaluated the quality and utility of the S192 MSS imagery of Kansas. 7. Communicated with members of the Kansas Geological Survey by telephone and correspondence.	1. Communicated via telephone and correspondence on the results of our combined work.	1. Found on U-2 and WB-57 airphotos (taken for this project) indications of possible late Cenozoic faulting near the site of the largest thermal power plant in Kansas (under construction), in Pottawatomie County east of Manhattan. Field studies are in progress. The only SL photo coverage of this site is by SL4 Pass 81 (S190B only) and is of little utility because the scene is snow-covered and quite overexposed.

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TABLE 0.5. WORK DONE UNDER THIS PROJECT IN EACH STATE, AND CHIEF ACCOMPLISHMENTS (Page 2 of 2)

WORK DONE		SCIENTIFIC/PRACTICAL ACCOMPLISHMENTS
By Principal Investigator and/or USGS assistants	By members of the state geological survey	(1) By P.I./USGS (2) By state geological survey
	MISSOURI	
1. Indexed and mapped coverage of all SL photos of Missouri. 2. Sent 1 copy of each SL photo to the State Geologist, with request for evaluation of their utility for scientific and practical work. 3. Evaluated the quality and utility for geomorphic/geologic mapping of all the SL photos of Missouri. 4. Determined coverage of S192 multispectral imagery of Missouri. 5. Sent 1 copy of the S192 MSS imagery of Missouri to the State Geologist. 6. Evaluated the quality and utility of the S192 MSS imagery of Missouri. 7. Mapped from S190A and S190B photos the analytic geomorphology of a large part of northeastern Missouri. 8. Mapped geologic linears in detail in part of northeastern Missouri near St. Louis. 9. Visited the state geological survey and discussed results of our combined efforts.	1. Conferred in person and via correspondence and telephone on the results of our combined work. 2. Utilized both the SL photos and the U-2 and WB-57 airphotos (taken for this project) as aids in preparing a map of the surficial deposits of Missouri (Scale 1:500,000).	1. Used SL S190A and S190B photos for preparing 1:475,000 and 1:713,000-scale maps of analytic geomorphology of a large part of northeastern Missouri. (1) 2. Utilized the SL photos (and the ultrahigh airphotos) in refining the mapping of surficial geology of the state. (2) 3. Used SL S190A and S190B photos for detailed mapping of geologic linears near St. Louis. (1) 4. Demonstrated feasibility of mapping strip-mined areas and of determining the degree of their reclamation and/or reforestation from S190A photos, and particularly, S190B photos. (1,2) 5. Demonstrated feasibility of mapping many limestone sinkholes, particularly from S190B photos. (1,2) 6. Found, by geomorphic mapping from SL photos, Landsat-1 images, and ultrahigh airphotos, supplemented by some stratigraphic field data, that much or all of the Mexico Plain (an extensive uplain plain near Mexico) may have been last glaciated in Illinoian time, not Kansan time as previously believed; thus, the western limit of Illinoian glaciation may lie as much as 75 miles west of the commonly accepted limit. (2)
	NEBRASKA	
1. Indexed and mapped coverage of all SL photos of Nebraska. 2. Sent 1 copy of each SL photo to the State Geologist, with request for evaluation of their utility for scientific and practical work. 3. Evaluated the quality and utility for geomorphic/geologic mapping of all the SL photos of Nebraska. 4. Mapped from S190B photos the analytic geomorphology of two large areas in northeastern Nebraska. 5. Mapped geologic linears in detail in the vicinity of Omaha. 6. Visited the state geological survey and discussed project results.	1. Conferred in person and via correspondence and telephone on the results of our combined work. 2. Utilized SL photos in mapping geologic linears in many parts of Nebraska and adjoining states.	1. Used S190B photos for preparing 1:250,00 and 1:475,000-scale maps of analytic geomorphology of two large areas in northeastern Nebraska. (1) 2. Used S190A photos for detailed mapping of geologic linears near Omaha. (1) 3. Used both S190A and S190B photos for mapping geologic linears in other parts of Nebraska (2,1).
	SOUTH DAKOTA	
1. Indexed and mapped coverage of all SL photos of South Dakota. 2. Sent 1 copy of each SL photo to the State Geologist. 3. Evaluated the quality and utility for geomorphic/geologic mapping of all the SL photos of South Dakota. 4. Mapped from S190A and S190B SL photos the analytic geomorphology of most of the Sioux Falls $1^{\circ} \times 2^{\circ}$ quadrangle, at scales ranging from 1:250,000 to 1:713,000. 5. Visited the state geological survey and discussed the project results.	1. Communicated by telephone and correspondence on the results of our combined work. 2. Used the SL photos as aids in interpreting both surficial and bedrock geology in the state.	1. Prepared analytic geomorphology maps (1:250,000 to 1:713,000 scale) from S190A and S190B photos of much of the Sioux Falls $1^{\circ} \times 2^{\circ}$ quadrangle. Found good agreement between boundaries we mapped vs those on available geologic maps, of the various drift plains (late and early Wisconsinan and Illinoian), and with known subdivisions of the late Wisconsinan drift plain. (1) 2. Noted a possible new bedrock structure in western South Dakota, which is being explored. (2)

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1.2 Preliminary evaluation of the quality of the Skylab photos and their utility for geomorphic/geographic mapping

We received a total of 1,699 separate SL photos, of which 1,290 were wholly or partly within the project region. In the latter group, 47.4% of the S190A and 49.2% of the S190B photos have less than 5% clouds, on the other hand, 48.0% of the S190A and 44.7% of the S190B photos have more than 30% clouds. Coverage within the 6-state region having less than 5% clouds totals about 420,000 sq km--about 39% of the total area of the 6 states (Fig. 1); nevertheless, repetitive, multiseasonal, cloud-free coverage by good-quality photos is very limited and many parts of the region have no coverage at all.

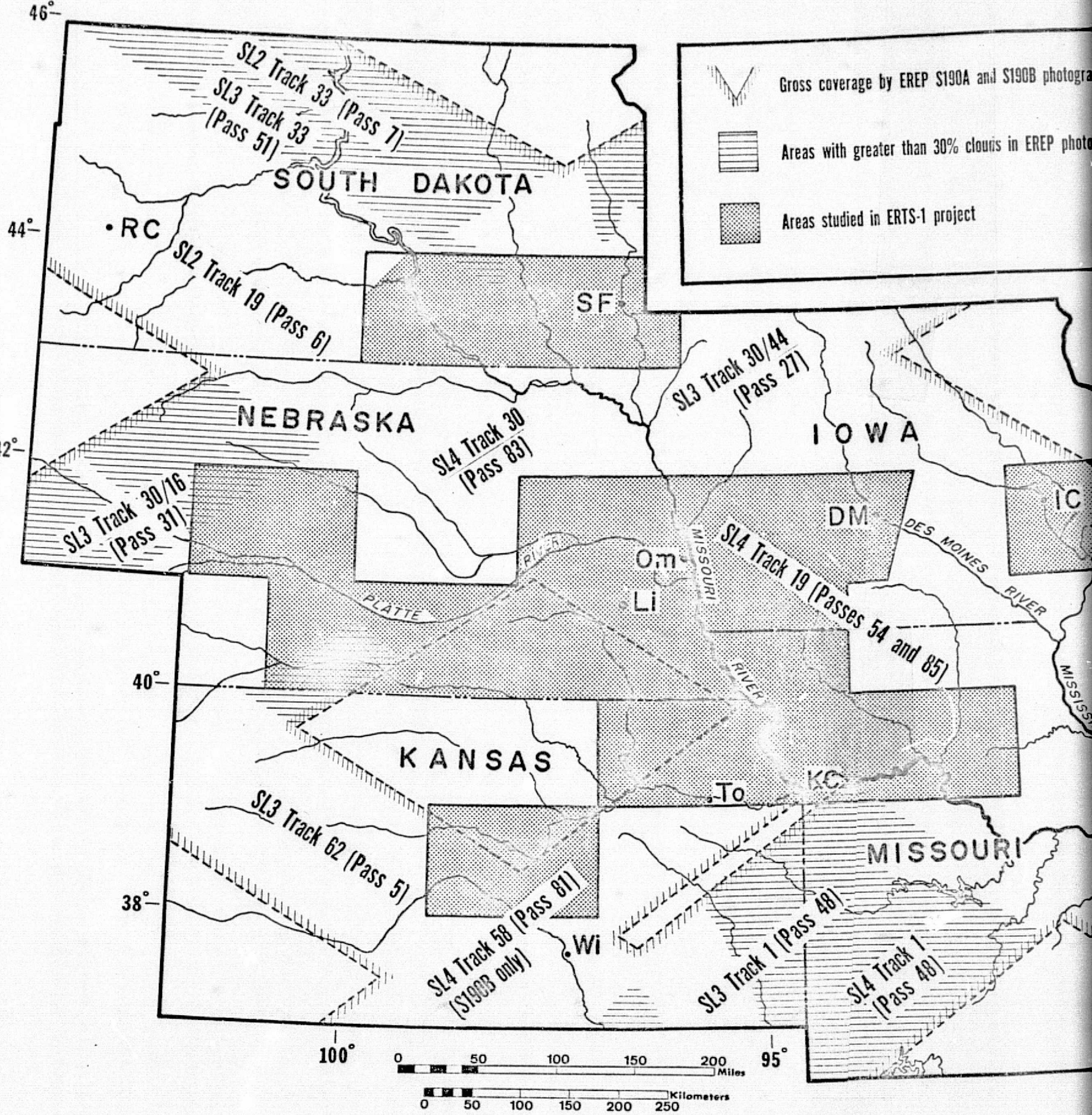
Figure 1.--NEAR HERE

In addition to indexing all the photos of the project region on both 1:1-million state base maps and on $1^{o} \times 2^{o}$ quadrangle maps, we evaluated all these photos in detail, in terms of cloud cover, usable frames, state coverage, photographic quality [sharpness of detail, exposure, contrast/gray-scale discrimination, and (for color and color-infrared photos) color balance], endlap, detectibility of roads and of stereorelief, and utility for mapping eight key geomorphic-geographic characteristics (Table 1). The evaluations were made in as quantitative terms as possible, using actual measured dimensions for factors such as detectibility, and a numerical rating system (1 = poor to 4 = excellent) where qualitative estimates were needed. Thus, the unenlarged photo transparencies from various bands and flights of the SL2, SL3 and SL4 missions can be directly compared in a fairly quantitative manner. A similar evaluation was made of the quality and utility of the photo images of 12 spectral bands from the S192 multispectral scanner in each of three scenes received (large areas in Kansas, Missouri, and Illinois; Table 3). In addition, the quality and utility for geomorphic/geographic mapping of the S190A and S190B photos were compared with S192 and ERTS (Landsat)-1 multispectral images of this region (Table 4).

Summarizing quality and utility in general terms: photos from the SL2 mission were taken on June 10, 1973, a good time of year for mapping geomorphology, soils, and surficial geology, because much bare ground is exposed in newly plowed croplands and foliage cover in pastures and woodlands still is relatively limited. These good to excellent photos are essentially cloud-free. Thus, overall, the SL2 photos have proved to be the most useful of all the SL photos. None of the photography taken on later missions achieved so favorable a combination of circumstances for obtaining maximum information for geomorphic-geologic mapping.

The SL3 photos were taken at the height of the growing season and near-maximum foliage conceals soils and surficial deposits and even minor details of topography. Extensive cloud cover and dense haze on most flights severely limit the usable coverage. In several flights, some frames are slightly to considerably underexposed (too dark) for the ground surface. Also, most flights did not provide sufficient endlap for continuous stereoscopic viewing.

The time of year when the SL4 photos were taken (late fall and winter) was of intermediate desirability compared with the SL2 and SL3 missions. In spite of much coverage that is useless because of clouds and dense haze, much coverage also was obtained with few or no clouds. Several flights have essentially



FOLDOUT FRAME 1

Figure 1. Coverage of project area by Skylab EREP photography.

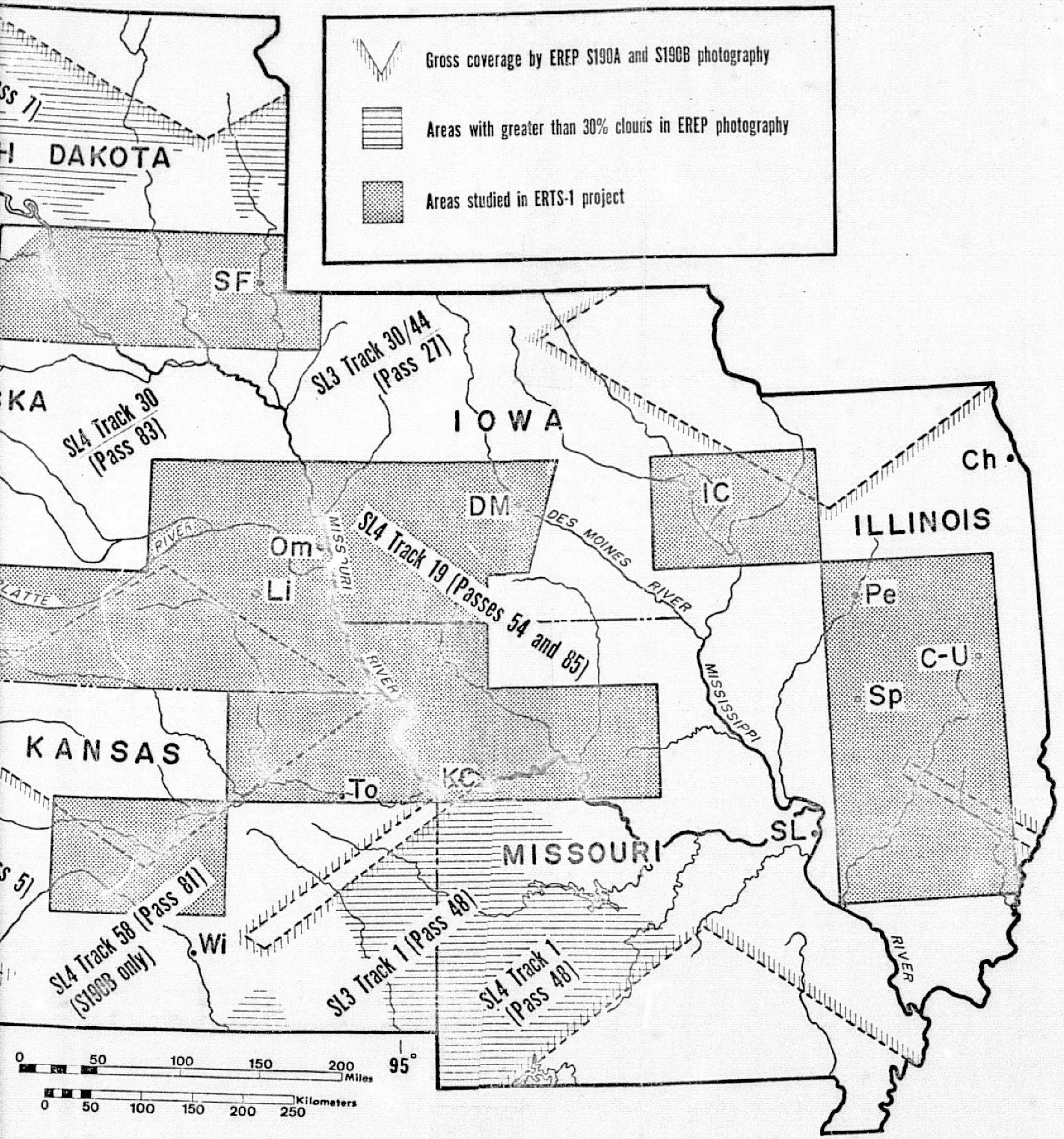


Figure 1 . Coverage of project area by Skylab EREP photography.

FOLDOUT FRAME 2

complete snow cover, others only partial snow cover. The snow cover conceals information on soils and surficial deposits and is particularly disadvantageous in the bands that are overexposed for the snowy areas (which generally is the case). The SL4 photos vary greatly in quality; part are very good to excellent (the sharpest of all SL photos), but unfortunately, many photos are poor quality to essentially useless because of severe overexposure for snow-covered areas (and in some cases, underexposure for the snow-free areas).

The unenlarged photo transparencies we received (3d generation) are much sharper than the enlargements (4 X of S190A and 2 X of S190B), though the quality of the enlargements varies somewhat from flight to flight of the various missions. The relatively poor sharpness of the enlargements was a serious drawback because we were obliged to use the enlargements for most of our photointerpretive mapping.

The S190B photos invariably yielded significantly more geomorphic information, in greater detail, than any S190A photos. For the S190A multispectral photos, the most useful bands for geomorphic mapping are the color and the color-infrared bands--in some cases the color band is the best, in other cases, the color-IR. The color photos (0.4-0.7 μm) provide the most information on geomorphology, geology, and soils. They have better resolution than the other multispectral bands, permitting maximum detail of mapping; however, they also show much distracting detail not related to geomorphology, geology, and soils (particularly, field patterns and differences in growth and type of crops); also, they have poor haze penetration. The color-IR photos (0.5-0.88 μm) show well the differences in soil drainage and moisture, and vegetative types, but has substantially lower ground resolution than the color and B/W red bands. The B/W-red band (0.6-0.7 μm) is superior for topographic detail and stream alignments, but generally is less useful than the color band. The two B/W-infrared bands (0.7-0.8 and 0.8-0.9 μm) have the poorest resolution, particularly in the excessively grainy SL2 photos; however, they have very good haze penetration and show the various water bodies and the differences in soil moisture especially well. The B/W-IR photos from SL2 were taken on June 10, a good time of year for distinguishing differences in soil moisture and drainage. The B/W "far" IR band shows these differences somewhat better than the B/W "near" IR band. Both B/W-IR bands are relatively poor for distinguishing woodlands from croplands, topographic detail, and outlines of urbanized areas. The B/W-green band (0.5-0.6 μm) generally is so low contrast and degraded by haze as to be nearly useless, except in several SL4 flights, when haze was less severe.

1.3 Detailed evaluations of the quality and utility of Skylab photographs made by using them for mapping analytic geomorphology in selected test areas

As explained above, a key means of evaluating the Skylab photos was to use them to prepare photointerpretive maps of analytic geomorphology in different parts of the Great Plains-Midwest that represent the main subdivisions of this large region in terms of topography, surficial deposits, climate, natural vegetation, soils, and land use. Our aim was to map natural landscape units that can be identified in terms of factors (slope, local relief, terrain profile, drainage density and pattern, soil color, and soil drainage) that can be directly interpreted from features visible on the photographs, such as tone, pattern, texture, color, stereorelief, and land use. The test (study) areas are:

(1) The South Dakota and Iowa portions of the Sioux Falls 1° x 2° quadrangle.

(2) Northeastern Nebraska-western Iowa--parts of the Sioux City, O'Neill, Broken Bow, Fremont, Omaha, and Nebraska City 1° x 2° quadrangles.

(3) Northeastern Missouri (and a small area in western Illinois)--parts of the Centerville, Jefferson, Moberly, Quincy, and St. Louis 1° x 2° quadrangles.

(4) Central and southern Illinois.-- parts of the Belleville, Burlington, Davenport, Decatur, Paducah and Peoria 1° x 2° quadrangles.

These are the first maps that portray the geomorphology of large parts of the Great Plains-Midwest in reasonably detailed quantitative-descriptive terms. They give secondary attention to the general character of the surficial deposits. An important feature of the explanation for each map is a rating system for each map unit in terms of environmental geomorphic/geologic limitations or advantages for the following factors: topography, availability of shallow ground water, gravel availability and quality, rock availability and quality, slope stability, foundation conditions, ease of excavation, road construction, surface drainage, soil (internal) drainage, erodibility of soils, and sites for sanitary landfills, sewage lagoons, and septic tanks. Such information is useful for regional land-use planning and management, exploration for ground water and construction materials, and other environmental geomorphologic/geologic applications.

We experimented with several techniques and instruments to determine those most efficient for the evaluative photointerpretive mapping. Where the photos provide stereoscopic coverage, the procedure most used was to examine 2 X and 4 X positive-transparency enlargements of the S190B or S190A photos (mainly the color, CIR, and B/W red bands) under an Old Delft scanning stereoscope at 1.5 and 4.5 X magnification. We also made considerable use of a Kern PG-2 stereoplotter, using either the unenlarged S190B color transparencies or 4 X enlargements of the color (or rarely, the CIR or B/W red) S190A bands. In addition, we occasionally projected the unenlarged 70mm S190A transparencies (various bands) onto transparent drafting film and mapped the landscape units visible on the enlarged image.

1.4 General conclusions on overall value of the Skylab photographs

The better SL photos provide overviews of large areas in the best detail so far available from space images of the Great Plains-Midwest. They are important new tools for geomorphologic and geologic mapping. Space photos such as these, with their synoptic, uniformly illuminated coverage, provide exceptional opportunities to integrate both the strongly and subtly imaged features without the noise of distracting detail, and consequently to determine relationships that might be missed by photointerpretation of aerial photographs alone. They permit significantly greater detail of mapping than the Landsat-1 MSS images, although their stereorelief and sharpness of detail is much inferior to ultrahigh (e.g., U-2 and RB-57) airphotos. On the one hand, they commonly show larger relationships such as end moraines and morainic systems, many geologic linears, and various geomorphologic-geologic anomalies better than airphotos. On the other hand, many known features are not evident, such as details of moraine patterns, stream terraces, faults, and bedrock units.

The maximum appropriate scale for comprehensive mapping of geomorphic features varies not only with the type, quality, and spectral band of the SL photos, but also with atmospheric conditions, local relief, land-use (especially cropland) patterns, and amounts of vegetative or snow cover. In the Great Plains-Midwest, several factors commonly tend to limit the accuracy with which boundaries between geomorphologic units can be drawn: (1) atmospheric haze, (2) small, commonly gradual, differences in local relief (that are difficult to perceive with the limited stereorelief detectability from SL photos), (3) field patterns in farming areas that commonly cut across and obscure all but the more pronounced changes in slope, and (4) vegetative cover during the growing season, ranging from crops of various types to pastures and woodlands in various stages of growth. These factors result in a generally lower obtainable accuracy of geomorphologic mapping than is possible in the Principal Investigator's companion Skylab project in southern Arizona (Task 335, EPN 489).

With the better S190B photos and favorable atmospheric and ground conditions, the boundaries of geomorphic units that are sharply defined by changes in slope and/or land-use (field) patterns can be mapped accurately (with accuracy approaching National Map Accuracy Standards) at scales as large as about 1:150,000; however, the more subtly defined boundaries cannot be mapped accurately at scales so large. Our experience has shown that 1:250,000 is the largest scale that is warranted for comprehensive geomorphologic mapping from high-quality S190B photos with relatively favorable atmospheric and ground conditions (e.g., see Appendix Figure A4.2). Individual high-contrast features, of course, can be mapped accurately at larger scales. Similarly, from the better S190A color, CIR, and B/W red photos, map scales of about 1:500,000 are warranted for comprehensive mapping of geomorphologic units under favorable atmospheric and ground conditions.

The SL photos are best used with awareness of their special advantages and limitations, as mapping tools intermediate between, and in conjunction with, coarser-resolution images (such as Landsat-1 MSS images) and finer-resolution ultrahigh and conventional airphotos.

1.5 Recommendations for future earth-resource photographic missions from satellites

1. Continue to use

   a. Multispectral camera arrays

   b. Earth-Terrain cameras with focal lengths of at least 18 inches (longer if possible).

   c. High-resolution color and B/W films. (These provide not only greater ground resolution but also better stereorelief-viewing capability.)

   d. Color films that enhance reddish hues, such as SO 242 and SO 356.

2. Provide 60% endlap coverage on all photographic passes. This will provide a capability for stereorelief viewing.

3. Take care to avoid photographing areas with more than 30% cover of clouds and/or dense haze. (Film saved by observing this precaution could provide for recommendation 2.)

4. Operate at an orbital altitude substantially lower than that of Skylab-A. This will provide better stereorelief.

5. Take photography at optimum times-of-year, such as:

   a. Spring (best time of year for geomorphologic-geologic mapping).

   b. Late fall, after foliage has decreased.

   c. Winter, when foliage is minimal. Both scenes bare of snow and those that are snow-covered are desirable, but care should be taken to avoid under- or over-exposure.

6. Experiment with photography at low sun-elevation angles, taken in early morning and/or late afternoon (local time), particularly in winter, spring, and fall.

7. Watch the exposure. In the SL3 mission, many color and CIR frames were underexposed (too dark) for the ground terrain, especially where clouds are present; a few B/W frames were considerably overexposed. In the SL4 mission, color and CIR photos commonly were overexposed, expecially for snow-covered areas.

8. Attempt repetitive multiseasonal coverage of the same areas.

9. Utilize a multispectral scanner system that has capability for high <u>spatial</u> resolution (now being perfected) in addition to high spectral resolution.

2.0 GENERAL BACKGROUND ON EVALUATIVE PROCEDURES

2.1 Staff personnel and collaborators

Most of the evaluative/interpretive investigations in this project were performed at the facilities of the U.S. Geological Survey, Denver Federal Center, Denver, Colorado, under the direction of Dr. Roger B. Morrison, Principal Investigator. Assisting in these studies at Denver for periods of two to several months at various times were H. Kit Fuller, Richard K. Rinkenberger, James R. Muhm, and John Prohaska.

The state geological surveys of Illinois, Iowa, Kansas, Missouri, Nebraska, and South Dakota collaborated in the project. They gave valuable assistance, both in the initial selection of study areas for geomorphic mapping and in evaluating the results of the mapping done at Denver. In several cases they also supplied ground-control information on anomalous features and possible new discoveries found by the interpretive mapping. Dr. Jerry A. Lineback, of the Illinois State Geological Survey, made an extensive comparison of the value of ERTS-1 images and Skylab photographs for mapping geologic features in Illinois (Lineback, 1974). Dr. Merlin Tipton, Assistant State Geologist of South Dakota, evaluated the geomorphic mapping in the South Dakota portion of the Sioux Falls $1^{\circ} \times 2^{\circ}$ quadrangle in terms of the surficial (mainly glacial) geology. Dr. William H. Allen, Jr., of the Missouri Division of Geological Survey and Water Resources, made a similar evaluation of the utility of Skylab photos for mapping surficial deposits in an area in northeastern Missouri. (Table 0.5.)

2.2 Indexing and preliminary evaluation of Skylab S190A and S190B photographs

We received at Denver the Skylab photographs listed in Tables 1 and 2. These were third-generation positive-transparency copies of both the unenlarged and enlarged photos. Individual copies of the various kinds of photos and images totalled as follows: for S190A, 222 scenes X 6 multispectral bands = 1,332 separate photographs, for S190B, 352 scenes/photos (1 band only); and for S192, 3 scenes X 12 multispectral bands = 36 images—a grand total of 1,720 photographs and images for the project region. These photographs were received in duplicate (both unenlarged and enlarged copies) and the duplicate copies were sent to the collaborating State Geologists.

Soon after receipt, the photographs and images were indexed on 1:1 million-scale base maps of the collaborating states, and also on 1:250,000-scale $1^{\circ} \times 2^{\circ}$ quadrangle maps. Figure 1 shows the coverage of the project region by SL photos. Coverage with less than 30% clouds totals about 420,000 sq km, about 39% of the 6-state region.

The photographs also were evaluated in terms of cloud cover, usable frames, state coverage, photographic quality, endlap, detectibility of roads and of stereorelief, and utility for mapping eight key geomorphic-geographic characteristics (Table 1). Photographic quality of both unenlarged and enlarged photos was evaluated for the areas in the photographs without clouds and dense haze, in terms of sharpness of detail, contrast, exposure, and (for color and color-infrared films) color balance; any other defects (such as scratches and other blemishes) also were noted. A numerical rating scale was used for each factor, ranging from 0 (none) to 1 (poor), 2 (fair), 3 (good), and 4 (excellent). The average (mean) quality rating, given for each multispectral band, provides a comparison of the relative overall quality of the various bands.

Other attributes of the photos that are of practical importance to evaluate are the minimum limits of two types of detectibility: linear features and stereorelief (for those photos with sufficient endlap for full stereoscopic coverage). Roads were used as a convenient means of measuring the minimum detectibility of linear features of moderately high to high contrast. They provide the best standard basis for comparison because they are the commonest easily identified linear features whose widths can be easily measured or estimated. Each SL photograph was examined under 7 to 20 X magnification to observe the narrowest roads detectible. To determine the width of these roads (which can range from private driveways to farm roads, county roads, state and federal highways and freeways), the same or similar roads were measured with a hand 20 X comparator on U-2 or WB-57 airphotos of the same or closely similar areas. This type of ground control from the airphotos eliminates inaccuracies caused by "blooming" and fuzzy definition of these relatively high-contrast features in some SL photographs (often a road that contrasts strongly with its background shows on the photos as wider than its true width). The measured road widths are restricted to the bare road surfaces and do not include side berms, ditches, or other features of the whole road right-of-way; the bare road surfaces generally contrast strongly with the adjoining vegetated terrain.

Stereorelief detectibility was determined by examining stereopairs of the transparencies under an Old Delft stereoscope (4.5 X magnification) and/or a Kern PG-2 stereoplotter (5 to 10 X magnification) and comparing the minimum discernible stereorelief on steep to moderately steep slopes with the actual relief shown on 7 1/2 to 15-minute topographic quadrangle maps. For the S190A photos, only the 4 X transparency enlargements were used because our stereoviewing equipment could not accomodate the 70 mm transparencies. For the S190B photos, both the 5-inch unenlarged transparencies and the 2 X transparency enlargements were measured.

Eight key criteria were used to evaluate the utility of the photographs for geomorphic-geographic mapping--the detail in which they show (1) land-surface-form factors of slope, local relief, and terrain profile, (2) vegetation/agricultural land-use characteristics, (3) dark vs light-colored soils, (4) well vs poorly drained soils, (5) stream order and pattern, (6) valley lowlands, (7) water surfaces (lakes, ponds, flowing streams), and (8) urbanized areas. These criteria were selected to emphasize the inherent advantages and disadvantages of the various spectral bands. This evaluation is based on the unenlarged transparencies (3d generation), and was made for all the areas free of clouds and dense haze along a flight path within the project region (states covered by the project). The same numerical rating scale was used for photographic

Table 1 near here.

TABLE I. EVALUATION CHART FOR SKYLAB PHOTOGRAPHS OF ILLINOIS, IO

SYSTEM Track/ flight date)	PASS/ ORBIT NUMBER	ROLL NO Band Spectral range[5] (film type)	FRAME[1] NUMBERS	CLOUD COVER 0-5%	 5-30%	 >30%	USABLE FRAMES Total no. in project area Fully	 Partly	STATE COVERAGE (frame nos.)	PHOTOGRAPHIC QUALITY[2] of transparencies (3d generation) A= sharpness of detail B= contrast C= color balance D= exposure E= average (mean) quality UNENLARGED (70 mm for S190A; 5-inch for S190B)	 ENLARGED (4 X for S190A; 2 X for S190B)	ENDLAP (%)	DETECT (minimum in STEREO-RELIEF
											SKYLAB 2		
190A 19 5/10/73)	6	10 Color 0.4-0.7μm (SO-356)	120-154 (120-150)	120-154	—	—	28	2	S.D. (120-128) Neb. (127-135) Ia. (133-137) Mo. (136-148) Ill. (141-150)	A=4 B=3 C=4 D=4 E=3.8	A=3 B=3 C=3.5 D=3.5 E=3.3	60	(ca. 20
		9 Color-IR 0.5-0.88μm (2443)	Do.	Do.	—	—				A=2.5 B=4 C=3.5 D=4 E=3.5	A=2 B=3 C=3 D=3 E=2.8		(ca. 15
		8 B/W-IR 0.8-0.9μm (2424)	112-146 (112-142)	112-146	—	—			S.D. (112-120) Neb. (119-127) Ia. (125-129) Mo. (128-140) Ill. (133-142)	A=0.5 B=2.5 C=— D=3 E=2.0	A=0.5 B=2 C=— D=3 E=1.8		(ca. 20
		7 B/W-IR 0.7-0.8μm (2424)	Do.	Do.	—	—				A=0.5 B=2 C=— D=3 E=1.8	A=0.5 B=1.5 C=— D=3 E=1.7		(0)
		11 B/W-red 0.6-0.7μm (SO-022)	Do.	Do.	—	—				A=4 B=4 C=— D=4 E=4.0	A=3.5 B=2.5 C=— D=3.5 E=3.2		(ca. 15
		12 B/W-green 0.5-0.6μm (SO-022)	Do.	Do.	—	—				A=2 B=1.5-2 C=— D=3 E=2.3	A=1-1.5 B=1.5 C=— D=3 E=1.9		(ca. 20
190B 19 5/10/73)	6	81 Color 0.4-0.7μm (SO-242)	156-201 (156-195)	156-201	—	—	37	2	S.D. (156-167) Neb. (164-177) Ia. (174-180) Mo. (177-194) Ill. (187-195)	A=4 B=3 C=4 D=4 E=3.8	A=2.5 (edges 1.5) B=3 C=3 D=3 E=2.9	60	ca. 8 (ca. 10
190A 33 5/10/73)	7	10 Color 0.4-0.7μm (SO-356)	232-260 (232-258)	241-260	240	232-239	8	11	S.D. (232-242) Ia. (241-251) Ill. (250-258)	A=3.5-4 B=2.5-3.5 C=2-3.5 D=2-3.5 E=3.1	A=2.5-3 B=2 C=2 D=2-3 E=2.3	60	(ca. 20
		9 Color-IR 0.5-0.88μm (2443)	Do.	Do.	Do.	Do.				A=2.5-3 B=3.5 C=2.5-3.5 D=1.5-2.5 E=2.8	A=1.5 B=2.5-3 C=2-3 D=1.5-2.5 E=2.2		(ca. 20
		8 B/W-IR 0.8-0.9μm (2424)	216-244 (216-242)	225-244	224	216-223			S.D. (216-226) Ia. (225-235) Ill. (234-242)	A=2.5 B=3.5 C=— D=2.5-3.5 E=3.0	A=1.5 B=2.5 C=— D=1.5-3 E=2.1		(ca. 20
		7 B/W-IR 0.7-0.8μm (2424)	Do.	Do.	Do.	Do.				A=1.5-2 B=2.5 C=— D=2-3 E=2.3	A=1.5 B=2 C=— D=2.5 E=2.0		(ca. 20
		11 B/W-red 0.6-0.7μm (SO-022)	Do.	Do.	Do.	Do.				A=3.5-4 B=3.5 C=— D=3.5 E=3.5	A=3 B=2.5 C=— D=2.5 E=2.7		(ca. 20
		12 B/W-green 0.5-0.6μm (SO-022)	Do.	Do.	Do.	Do.				A=2 B=1.5 C=— D=3 E=2	A=1.5 B=2 C=— D=3 E=2.2		(ca. 20
190B 33 5/10/73)	7	81 Color 0.4-0.7μm (SO-242)	307-342 (307-339)	317-342	315-316	307-314	18	8	S.D. (307-318) Ia. (317-329) Ill. (328-339)	A=4 B=2.5-3.5 C=2.5-4 D=2-3 E=3.2	A=2 B=2.5 C=2 D=2.5 E=2.3	60	ca. 8 (ca. 10

FOOTNOTES

Frames listed in parenthesis are wholly or partly within the project region.

Numerical rating system for photographic quality and utility for geomorphic-geographic mapping: 0 = none (nil); 1 = poor; 2 = fair; = good; 4 = excellent.

[3] Numbers not in parenthesis refer to unenlarged transparencies; numbers in parenthesis apply to transparency enlargements. See last sheet for detailed discussion of detectibility measurements.

[4] Evaluati based on haze. A r tions and utility o

[5] See Table

LDOUT FRAME /.

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OIS, IOWA, KANSAS, MISSOURI, NEBRASKA, AND SOUTH DAKOTA (page 1 of 5)

ENDLAP (%)	DETECTIBILITY[3] (minimum dimension in meters): STEREO-RELIEF	DETECTIBILITY[3]: ROADS	UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS[2,4]: Land-surface-form factors (slope, local relief, profile)	Vegetation/agricultural land-use characteristics	Dark vs light-colored soils	Well vs poorly drained soils	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS: Individual bands: quality and utility	Summary for flight (all bands)
2														
0	(ca. 20)	ca. 7 (ca. 10)	2.5-3.5	1.5-3	3.5	0	2.5-3.5	2-3	1-2	3.5		2.4	Best quality and generally most useful of the 6 bands for GG mapping. 70 mm tsp. have near-excellent photo quality; enl. are somewhat lower quality in all respects.	Essentially cloud-free. Good time-of-year for near-minimum vegetation and near-maximum information on surficial materials, soils, and landforms. Stereoscopic coverage also is highly advantageous. Color band is highest quality and most useful, CIR band is very good quality and almost as useful for GG mapping. B/W red band shows much detail on landforms and streams but less total GG information than the color and CIR bands. B/W farther near-IR band shows soil-moisture differences well, but otherwise has little utility. The B/W near-IR and B/W green bands are the least useful.
	(ca. 15)	ca. 10 (ca. 15)	2-3	2.5-3:5	0	2.5	2-3	2.5-3.5	2.5-3.5	1.5-2.5		2.3	Near-excellent photo quality except sharpness of detail is only fairly good in 70 mm and fair in enlarged tsp. Second-most useful band for GG mapping.	
	(ca. 20)	ca. 15 (ca. 25)	0-1	1-2	0	2-3	1	0-2.5	1-3	1		1.2	Very grainy and fuzzy; useless for landform detail. Larger water bodies contrast well; smaller ones do not because of low resolution. Gross soil-moisture differences show well but are difficult to separate from vegetation differences.	
	(0)	ca. 15 (ca. 25)	0-1	0.5-2	0	2-2.5	1	0-2	1-2.5	0.5		1.1	Similar to above (roll 8) except extremely grainy and fuzzy and somewhat less contrast, therefore less useful for GG mapping.	
	(ca. 15)	ca. 8 (ca. 10)	2.5-3.0	1.5-2.5	2-3.5	0	3.5	2.5-3.0	2	2.5-3.0		2.3	70 mm tsp. are excellent photo quality, but have somewhat less GG information than color and CIR bands. Enl. are too contrasty and less sharp than they should be.	
	(ca. 20)	ca. 10 (ca. 10)	1.5	1	1	0	1	1	1	1.5		1.0	Poorest of the S190A bands in utility for GG mapping because poor haze penetration and atmospheric scattering seriously degrade contrast and sharpness.	
0	ca. 8 (ca. 10)	< 5 (10)	3.5	2-3	3.5	0	3	3	2	3		2.6	Essentially cloud-free; taken at good time-of-year for obtaining information on surficial materials, soils, and landforms. Stereoscopic coverage also is highly advantageous. Photo quality and information content on GG features is very good for the 5-inch tsp., only good to fair for the enl. The enl. are slightly out-of-focus and have severe roll off (not vignetting) for ca. 3/4-inch around their outer margins, due to poor enlarger optics.	
0	(ca. 20)	ca. 7 (ca. 12)	2-3.5	1-3	2-3.5	0	1.5-3.5	1.5-3	1-2	2.5-3		2.1	70 mm are much better quality than the enl. Frames 239-246 are much under-exposed (too dark) and poorest quality. Enl. are much less sharp and with poorer color balance than they should be.	Cloud-free except in South Dakota NW of Sioux City. Color and CIR frames 239-246 are considerably under-exposed (too dark); remaining frames are slightly under-exposed. Under-exposure is less evident in the B/W bands. Good time-of-year (near-minimum vegetative cover) for photointerpretation of GG features.
	(ca. 20)	ca. 10 (ca. 15)	2-3	2-3	0	2-2.5	1.5-2.5	2-3	2-3	1.5-2.5		2.0	Like above, except enl. are even poorer quality, very grainy, much less sharp, with some red specks and long red scratch lines.	
	(ca. 20)	ca. 10 (ca. 12)	1	1-2	0	2-3.5	1	1.5-3	2-3.5	0.5-1.5		1.5	70 mm tsp. are much better exposed than the enl. and have better contrast, tone separation, and sharpness. Poor for details on landforms but good for soil-moisture differences.	
	(ca. 20)	ca. 10 (ca. 12)	1	1-2	0	2-3	1	1-2.5	1.5-3	0.5-1		1.3	Similar to above, but somewhat less contrast.	
	(ca. 20)	ca. 10 (ca. 12)	2-3	1-3	2-3	0	2-3.5	2-3	1-2	2-3.5		2.1	70 mm has near-excellent photo quality and shows details of landforms and streams very well; enl. are somewhat too contrasty, somewhat grainy, and have lost some detail.	
	(ca. 20)	ca. 12 (ca. 12)	1	1	1	0	1-1.5	1-1.5	1-1.5	1-1.5		1.0	Fair photo quality (haze degrades contrast and sharpness of detail); least useful band for GG mapping.	
0	ca. 8 (ca. 10)	ca. 5 (13)	3-4	1.5-3	2.5-4	0	2-4	2-3.5	1-2.5	3.5		2.5	Frames 314-322 are considerably under-exposed (too dark); remaining frames are somewhat under-exposed. Unenl. tsp. are very useful for mapping most GG features. Enl. are much less sharp than they should be and have washed-out color, which severely limits their utility for detailed mapping.	

Evaluation of utility for mapping geomorphic-geographic (GG) characteristics is based on areas in the unenlarged transparencies that are free of clouds and dense haze. A range in values is given where significant variations in atmospheric conditions and/or photographic exposure or processing occur along a flight. Commonly the utility of the enlargements is ½ to 1 rating unit lower for most characteristics.

ABBREVIATIONS

Do.	= ditto	enl.	= enlargements
B/W	= black-and-white	unenl.	= unenlarged
CIR	= color infrared	mm	= millimeter
GG	= geomorphic-geographic	NA	= not applicable
IR	= infrared	tsp.	= transparencies

See Table 5 for revised spectral ranges for B/W S190A bands.

FOLDOUT FRAME 2

TABLE I. EVALUATION CHART FOR SKYLAB PHOTOGRAPHS OF ILLINOIS, IOWA, KANSAS, MISSOUR

SYSTEM Track/ (flight date)	PASS/ ORBIT NUMBER	ROLL NO. Band Spectral range[5] (film type)	FRAME[1] NUMBERS	CLOUD COVER 0-5%	 5-30%	 >30%	USABLE FRAMES Total no. in project area Fully	 Partly	STATE COVERAGE (frame nos.)	PHOTOGRAPHIC QUALITY[2] of transparencies (3d generation) A= sharpness of detail B= contrast C= color balance D= exposure E= average (mean) quality UNENLARGED (70 mm for S190A; 5-inch for S190B)	 ENLARGED (4 X for S190A; 2 X for S190B)	ENDLAP (%)	DETECTIBILITY[3] (minimum dimension in meters) STEREO-RELIEF	 ROADS	UTILITY FOR MAPPING KEY GEOMO Land-surface-form factors (slope, local relief, profile)	 Vegetation/agricultural land-use characteristics	 Dark vs light-colored	 Well vs poorly	 Stream o	 Va
SKYLAB 3																				
S190A **1** (9/18/73)	48	46 Color 0.4-0.7µm (SO-356)	186-198 (188-197)	196-198	195	186-194	0	9	Kan. (188-192) Mo. (190-195) Ill. (194-200) Ia. (195-197)	A=3.5-4 B=2.5 C=3 D=3.5 E=3.2	A=2.5 B=3 C=3 D=3 E=2.9	60-0	(ca. 15)	ca. 7 (ca. 10)	3.5	3	2	0	3	3
		45 Color-IR 0.5-0.88µm (2443)	Do.	Do.	Do.	Do.				A=2 B=2.5-3 C=2.5 D=2.5 E=2.4	A 1.5 B 3 C=2.5 D=2.5 E=2.4		(ca. 30)	ca. 25 (ca. 40)	2.5	3.5	0	1	1.5	2
		44 B/W-IR 0.8-0.9µm (2424)	Do.	Do.	Do.	Do.				A=2 B=2.5 C=— D=3 E=2.5	A=1 B=2.5 C=— D=3 E=2.2		(0)	> 50 (> 70)	1	1.5	0	1	1	1
		43 B/W-IR 0.7-0.8µm (2424)	Do.	Do.	Do.	Do.				A=1.5 B=2 C=— D=2 E=1.8	A=1 B=2 C=— D=2 E=1.7		(0)	> 60 (> 80)	1	1	0	1	1	1
		47 B/W-red 0.6-0.7µm (SO-022)	Do.	Do.	Do.	Do.				A=4 B=3.5 C=— D=3.5 E=3.7	A=2.5 B=3 C=— D=3 E=2.8		(ca. 15)	ca. 5 (ca. 10)	3.5	2.5	1.5	0	3.5	3.5
		4[illegible] B/W-green 0.5-0.6µm (SO-022)	Do.	Do.	Do.	Do.				A=2 B=1.5 C=— D=3 E=2.2	A=1.5 B=1.5 C=— D=2.5 E=1.8		(ca. 15)	ca. 12 (ca. 25)	1	1	1	0	1	1-1.5
S190B **1** (9/18/73)	48	88 Color 0.4-0.7µm (SO-242)	210-227 (212-223)	219-222	223-224	210-218 225-227	1	11	Kan. (212-215) Mo. (214-218) Ill. (217-222)	A=4 B=3.5 C=4 D=3.5 E=3.8	A=3 B=3.5 C=4 D=3.5 E=3.5	60-0	NA	< 5 (ca. 8)	4	4	4	0	3	3.5
S190A **30/16** (9/10/73)	31	40 Color 0.4-0.7µm (SO-356)	053-060 (053-059)	—	060	053-059	0	3	S.D. (056-059) Neb. (053-057)	A=2-3 B=2-3 C=1.5-3 D=1.5-3 E=2.4	A=2 B=3 C=1.5-2.5 D=2.5 E=2.4	15	NA	ca. 8 (ca. 12)	1-2.5	1-2	1	0	1-2	1-2
		39 Color-IR 0.5-0.88µm (2443)	Do.	—	Do.	Do.				A=2 B=2 C=2 D=2 E=2.0	A=1.5 B=1.5 C=2 D=2 E=1.8		NA	ca. 10 (ca. 12)	1	1	0	1	1	1
		38 B/W-IR 0.8-0.9µm (2424)	Do.	—	Do.	Do.				A=1.5 B=1.5-2 C=— D=2.5 E=1.9	A=1 B=2 C=— D=2.5 E=1.8		NA	ca. 25 (ca. 35)	0	0.5	0	1	0.5	0.5
		37 B/W-IR 0.7-0.8µm (2424)	Do.	—	Do.	Do.				A=2 B=1.5 C=— D=2 E=1.8	A=1 B=1.5 C=— D=2-2.5 E=1.6		NA	ca. 25 (ca. 35)	0	0.5	0	0.5	0.5	0.5
		41 B/W-red 0.6-0.7µm (SO-022)	Do.	—	Do.	Do.				A=2-3.5 B=2-3 C=— D=3 E=2.7	A=2 B=2 C=— D=2 E=2.0		NA	ca. 7 (ca. 10)	2-3	2	1	0	2	1-2
		42 B/W-green 0.5-0.6µm (SO-022)	Do.	—	Do.	Do.				A=1-2.5 B=1-1.5 C=— D=3 E=2.0	A=1-2 B=1 C=— D=3 E=1.8		NA	ca. 10	0.5	0.5	0	0	0.5	0.5
S190B **30/16** (9/10/73)	31	85 B/W (SO-3414)	389-404 (389-403)	—	—	389-403	0	8	S.D. (394-403) Neb. (389-397)	A=3-4 B=2 C=— D=2.5 E=2.7	A=3-4 B=2 C=— D=2.5 E=2.7	60	ca. 10 (ca. 20)	ca. 5 (ca. 7)	2-3	2-3	1	0	2-3	2-3
S190A **30/44** (9/6/73)	27	34 Color 0.4-0.7µm (SO-356)	252-264 (254-259)	257-259	256	252-255 260-264	2	2	Ia. (258-259) S.D. (258) Neb. (254-258) Kan. (254-255)	A=2.5-3.5 B=2-3 C=2-3 D=1.5-3 E=2.6	A=3 B=3 C=3 D=2.5-3 E=2.9	15	NA	ca. 8 (ca. 10)	2-3	2-3	1	0	2-3	2-3
		33 Color-IR 0.5-0.88µm (2443)	Do.	Do.	Do.	Do.				A=2.5-3 B=2-3 C=2 D=1.5-2.5 E=2.3	A=2.5 B=3 C=3 D=3 E=2.9		NA	ca. 10 (ca. 12)	2-2.5	2-3	0	1-2	2	2
		32 B/W-IR 0.8-0.9µm (2424)	Do.	Do.	Do.	Do.				A=1.5-2 B=1.5-2 C=— D=3 E=2.2	A=1.5 B=3 C=— D=3 E=2.5		NA	ca. 25 (ca. 35)	0	1.5-2	0	1	0.5	0.5
		31 B/W-IR 0.7-0.8µm (2424)	Do.	Do.	Do.	Do.				A=1.5-2 B=1.5 C=— D=2.5-3 E=2.0	A=1.5 B=3 C=— D=3 E=2.5		NA	ca. 25 (ca. 35)	0	1.5	0	1	0.5	0.5
		35 B/W-red 0.6-0.7µm (SO-022)	Do.	Do.	Do.	Do.				A=2.5-3.5 B=1.5-3 C=— D=1.5-3 E=2.5	A=3 B=1.5 C=— D=1.5-3 E=2.3		NA	ca. 8 (ca. 10)	1-2	1.5	0.5	0	1	1
		36 B/W-green 0.5-0.6µm (SO-022)	Do.	Do.	Do.	Do.				A=1.5-2 B=0.5 C=— D=0.5 E=0.9	A=1-2 B=1 C=— D=1.5-2.5 E=1.5		NA	ca. 10 (ca. 12)	0.5	0.5	0	0	0.5	0.5
S190B **30/44** (9/6/73)	27	86 Color 0.4-0.7µm (SO-242)	024-040 (024-034)	030-034	029	026-028	5	1	Neb. (024-032) Kan. (026-027) S.D. (032) Ia. (032-034)	A=3-3.5 B=2.5 C=2-3 D=2-3 E=2.7	A=2.5-3.5 B=2.5 C=2-3 D=2-3 E=2.6	15-0	NA	ca. 7 (ca. 8)	2.5-3.5	2-3.5	0.5-2	0	2.5-3.5	2.5-3.5

FOOTNOTES

[1]Frames listed in parenthesis are wholly or partly within the project region.
[2]Numerical rating system for photographic quality and utility for geomorphic-geographic mapping: 0 = none (nil); 1 = poor; 2 = fair; 3 = good; 4 = excellent.

[3] Numbers not in parenthesis refer to unenlarged transparencies; numbers in parenthesis apply to transparency enlargements. See last sheet for detailed discussion of detectibility measurements.

[4] Evaluation of utility for mapping geomorphic based on areas in the unenlarged transparenci haze. A range in values is given where signi tions and/or photographic exposure or process utility of the enlargements is ½ to 1 rating.

[5] See Table 5 for revised spectral ranges for B

FOLDOUT FRAME 1

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TOGRAPHS OF ILLINOIS, IOWA, KANSAS, MISSOURI, NEBRASKA, AND SOUTH DAKOTA (page 2 of 5)

PHOTOGRAPHIC QUALITY[2] of transparencies (3d generation) A= sharpness of detail B= contrast C= color balance D= exposure E= average (mean) quality UNENLARGED (70 mm for S190A; 5-inch for S190B)	ENLARGED (4 X for S190A; 2 X for S190B)	ENDLAP (%)	DETECTIBILITY[3] (minimum dimension in meters) STEREO-RELIEF	ROADS	UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS[2,4] Land-surface-form factors (slopes, local relief, profile)	Vegetation/agricultural land-use characteristics	Dark vs light-colored soils	Well vs poorly drained soils	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS Individual bands: quality and utility	Summary for flight (all bands)
SKYLAB 3																
A=3.5-4 B=2.5 C=3 D=3.5 E=3.2	A=2.5 B=3 C=3 D=3 E=2.9	60-0	(ca. 15)	ca. 7 (ca. 10)	3.5	3	2	0	3	3	1-3	4		2.6	Despite considerable degradation by haze, sharpness of 70 mm tsp. is near-excellent and contrast fairly good, making them very useful for GG mapping. Graininess of the enl. considerably impairs their utility. Endlap 0-15% in NE end.	Poor time-of-year (near-maximum vegetation cover) for GG mapping. Pepper-and-salt pattern of clouds and cloud-shadows over most of project region (beginning 80-150 km SW of Chicago) severely limits the utility for GG mapping. However, in spite of some degradation by haze of the color and green bands, photo quality of 70 mm tsp. color, CIR, and red bands (most useful ones for GG mapping) is fairly good to very good. Enl. are considerably less sharp than they should be.
A=2 B=2.5-3 C=2.5 D=2.5 E=2.4	A=1.5 B=3 C=2.5 D=2.5 E=2.4		(ca. 30)	ca. 25 (ca. 40)	2.5	3.5	0	1	1.5	2	2-3	1.5		1.8	70 mm tsp. have poor sharpness but fairly good contrast and color balance. Enl. are very grainy, which decreases their utility for GG mapping.	
A=2 B=2.5 C=— D=3 E=2.5	A=1 B=2.5 C=— D=3 E=2.2		(0)	> 50 (> 70)	1	1.5	0	1	1	1	1-3.5	0.5-1		1.1	70 mm tsp. are quite grainy, enl. extremely so, making them of little utility for GG mapping. Difficult to distinguish cloud shadows from lakes and ponds.	
A=1.5 B=2 C=— D=2 E=1.8	A=1 B=2 C=— D=2 E=1.7		(0)	> 60 (> 80)	1	1	0	1	1	1	1-3	0.5-1		1.0	Similar to above, except less contrast, possibly because somewhat over-exposed.	
A=4 B=3.5 C=— D=3.5 E=3.7	A=2.5 B=3 C=— D=3 E=2.8		(ca. 15)	ca. 5 (ca. 10)	3.5	2.5	1.5	0	3.5	3.5	1.5	3		2.4	70 mm tsp. are near-excellent photo quality and very useful for GG mapping. Enl. are very grainy and somewhat less useful.	
A=2 B=1.5 C=— D=3 E=2.2	A=1.5 B=1.5 C=— D=2.5 E=1.8		(ca. 15)	ca. 12 (ca. 25)	1	1	1	0	1	1-1.5	1	1		0.9	Fair photo quality (haze degrades contrast and sharpness of detail); least useful band for GG mapping.	
A=4 B=3.5 C=4 D=3.5 E=3.8	A=3 B=3.5 C=4 D=3.5 E=3.5	60-0	NA	< 5 (ca. 8)	4	4	4	0	3	3.5	1-3	4		3.6	Poor time-of-year (near-maximum vegetative cover) for GG mapping. Pepper-and-salt cloud and cloud-shadow pattern over most of project region severely restricts utility for GG mapping. Photo quality of 5-inch tsp. is near-excellent; enl. are quite sharp and have good color. Mostly 60% endlap; 0-15% endlap in NE end.	
A=2-3 B=2-3 C=1.5-3 D=1.5-3 E=2.4	A=2 B=3 C=1.5-2.5 D=2.5 E=2.4	15	NA	ca. 8 (ca. 12)	1-2.5	1-2	1	0	1-2	1-2	1-2	1-2.5		1.3	70 mm in eastern S. Dakota (057-060) are somewhat under-exposed, which, with some haze, reduces sharpness, contrast, and color balance. Enl. are somewhat better exposed but moderately grainy and fuzzy.	Utility very limited because of excessive cloud cover and haze. Photo quality (70 mm and enl.) fair to mostly poor. Poor time-of-year for GG mapping--vegetative cover tends to obscure GG features.
A=2 B=2 C=2 D=2 E=2.0	A=1.5 B=1.5 C=2 D=2 E=1.8		NA	ca. 10 (ca. 12)	1	1	0	1	1	1	1.5	1-2.5		1.0	70 mm are poor quality, considerably under-exposed (too dark) and quite grainy. Enl. are even poorer, very grainy. Very low utility for GG mapping.	
A=1.5 B=1.5-2 C=— D=2.5 E=1.9	A=1 B=2 C=— D=2.5 E=1.8		NA	ca. 25 (ca. 35)	0	0.5	0	1	0.5	0.5	0.5-3	0.5		0.6	70 mm are very grainy and fuzzy; enl. are extremely grainy and low resolution. Nearly useless for GG mapping.	
A=2 B=1.5 C=— D=2 E=1.8	A=1 B=1.5 C=— D=2-2.5 E=1.6		NA	ca. 25 (ca. 35)	0	0.5	0	0.5	0.5	0.5	0.5-2.5	0.5		0.5	Similar to above.	
A=2-3.5 B=2-3 C=— D=3 E=2.7	A=2 B=2 C=— D=2 E=2.0		NA	ca. 7 (ca. 10)	2-3	2	1	0	2	1-2	0.5-2	1-2.5		1.5	70 mm are fairly good photo quality despite local degradation by haze. Enl. are somewhat grainy and fuzzy.	
A=1-2.5 B=1-1.5 C=— D=3 E=2.0	A=1-2 B=1 C=— D=3 E=1.8		NA	ca. 10	0.5	0.5	0	0	0.5	0.5	0.5	1		0.4	Poor sharpness and low contrast because of haze render this band (both 70 mm and enl.) the least useful for GG mapping.	
A=3-4 B=2 C=— D=2.5 E=2.7	A=3-4 B=2 C=— D=2.5 E=2.7	60	ca. 10 (ca. 20)	ca. 5 (ca. 7)	2-3	2-3	1	0	2-3	2-3	1	3		1.9	Very sharp detail but somewhat under-exposed (too dark), especially in eastern South Dakota, which, with some haze, somewhat reduces sharpness, contrast, and utility for GG mapping. Better endlap than S190A.	
A=2.5-3.5 B=2-3 C=2-3 D=1.5-3 E=2.6	A=3 B=3 C=3 D=2.5-3 E=2.9	15	NA	ca. 8 (ca. 10)	2-3	2-3	1	0	2-3	2-3	1	4		2.0	Frames 258-261 are badly under-exposed (too dark), which degrades contrast, sharpness, and color balance; 256-257 are somewhat under-exposed; 252-255 are well exposed but have much clouds & haze. Enl. are better exposed.	Frames 256-259 have few clouds and are mostly haze-free; frames 252-255 and 261-264 have very limited utility because of much cloud cover and haze. Frames 258-261 in 70 mm format are badly under-exposed (too dark) in the color, CIR, B/W red and B/W green bands; enl. are better exposed. Lack of stereoscopic coverage restricts utility for GG-mapping.
A=2.5-3 B=2-3 C=2 D=1.5-2.5 E=2.3	A=2.5 B=3 C=3 D=3 E=2.9		NA	ca. 10 (ca. 12)	2-2.5	2-3	0	1-2	2	2	1.5-3	3		1.9	Similar to above, except somewhat less sharp.	
A=1.5-2 B=1.5-2 C=— D=3 E=2.2	A=1.5 B=3 C=— D=3 E=2.5		NA	ca. 25 (ca. 35)	0	1.5-2	0	1	0.5	0.5	1.5-2.5	0.5		0.8	Exposure good for all frames. Low sharpness, especially the enl. which are very grainy but have better contrast than the 70 mm. Very limited utility for GG mapping; shows mainly the larger streams, lakes, & reservoirs.	
A=1.5-2 B=1.5 C=— D=2.5-3 E=2.0	A=1.5 B=3 C=— D=3 E=2.5		NA	ca. 25 (ca. 35)	0	1.5	0	1	0.5	0.5	1.5-2.5	0.5		0.8	Similar to above, except less contrast.	
A=2.5-3.5 B=1.5-3 C=— D=1.5-3 E=2.5	A=3 B=1.5 C=— D=1.5-3 E=2.3		NA	ca. 8 (ca. 10)	1-2	1.5	0.5	0	1	1	0.5	3		1.1	Same frames are too dark (under-exposed) as in the color and CIR bands; sharpness is fairly good to very good; contrast is fairly poor to good (70 mm) or fairly poor (enl.).	
A=1.5-2 B=0.5 C=— D=0.5 E=0.9	A=1-2 B=1 C=— D=1.5-2.5 E=1.5		NA	ca. 10 (ca. 12)	0.5	0.5	0	0	0.5	0.5	0.5	1.5		0.8	Same frames as in the color and CIR bands are extremely dark (under-exposed), thus most of frames in the relatively cloud and haze-free areas are essentially useless for GG mapping.	
A=3-3.5 B=2.5 C=2-3 D=2-3 E=2.7	A=2.5-3.5 B=2.5 C=2-3 D=2-3 E=2.6	15-0	NA	ca. 7 (ca. 8)	2.5-3.5	2-3.5	0.5-2	0	2.5-3.5	2.5-3.5	2.5	4		2.4	Frames 029-034 are mostly cloud and haze-free and show very good detail for GG mapping; 024-028 have considerable cloud cover and haze. Lack of stereoscopic coverage limits utility for GG mapping.	

NOTES

s refer to unenlarged trans-
thesis apply to transparency
t for detailed discussion of

[4] Evaluation of utility for mapping geomorphic-geographic (GG) characteristics is based on areas in the unenlarged transparencies that are free of clouds and dense haze. A range in values is given where significant variations in atmospheric conditions and/or photographic exposure or processing occur along a flight. Commonly the utility of the enlargements is ½ to 1 rating unit lower for most characteristics.

[5] See Table 5 for revised spectral ranges for B/W S190A bands.

ABBREVIATIONS

Do. = ditto		enl. = enlargements	
B/W = black-and-white		unenl. = unenlarged	
CIR = color infrared		mm = millimeter	
GG = geomorphic-geographic		NA = not applicable	
IR = infrared		tsp. = transparencies	

FOLDOUT FRAME 2

TABLE I. EVALUATION CHART FOR SKYLAB PHOTOGRAPHS OF ILLINOIS, IOWA, KANSAS, MISS

SYSTEM Track/ (flight date)	PASS/ ORBIT NUMBER	ROLL NO. Band Spectral range[5] (film type)	FRAME[1] NUMBERS	CLOUD COVER 0-5%	 5-30%	 >30%	USABLE FRAMES Total no. in project area Fully	 Partly	STATE COVERAGE (frame nos.)	PHOTOGRAPHIC QUALITY[2] of transparencies (3d generation) A= sharpness of detail B= contrast C= color balance D= exposure E= average (mean) quality UNENLARGED (70 mm for S190A; 5-inch for S190B)	 ENLARGED (4 X for S190A; 2 X for S190B)	ENDLAP (%)	DETECTIBILITY[3] (minimum dimension in meters) STEREO-RELIEF	 ROADS	UTILITY FOR MAPPING KE… Land-surface-form factors (slope, local relief, pro…	 Vegetation/agriculture land-use character…	 Dark vs ligh…	 Well y…
										SKYLAB 3								
S190A **33** (9/20/73)	51	46 Color 0.4-0.7μm (SO-356)	251-267 (255-265)	—	262	251-261 263-267	0	3	Ia. (255-263) Ill. (262-265)	A=1-2.5 B=1-2 C=2 D=3 E=2.1	A=1-2 B=1-2 C=2 D=3 E=2.0	15- 60	(ca. 20)	ca. 8 (ca. 9)	1- 2.5	1-2	0.5	0
		45 Color-IR 0.5-0.88μm (2443)	Do.	—	Do.	Do.				A=1-2 B=3 C=3 D=3 E=2.6	A=1-2 B=3.5 C=3.5 D=3.5 E=3.0		(ca. 45)	ca. 10 (ca. 11)	1-2	1- 2.5	0	1
		44 B/W-IR 0.8-0.9μm (2424)	Do.	—	Do.	Do.				A=1 B=1.5 C=— D=3 E=1.8	A=1 B=2 C=— D=3 E=2.0		(0)	ca. 30 (ca. 40)	0.5	0.5	0	1
		43 B/W-IR 0.7-0.8μm (2424)	Do.	—	Do.	Do.				A=0.5 B=1 C=— D=2 E=1.2	A=0.5 B=1.5 C=— D=2.5 E=1.5		(0)	ca. 40 (ca. 50)	0.5	0	0	0.5
		47 B/W-red 0.6-0.7μm (SO-022)	Do.	—	Do.	Do.				A=3.5 B=2-3 C=— D=3 E=3.0	A=3.5 B=3.5 C=— D=3.5 E=3.5		(ca. 20)	ca. 6 (ca. 8)	1.5- 2.5	1.5- 2.5	1	0
		48 B/W-green 0.5-0.6μm (SO-022)	Do.	—	Do.	Do.				A=1-1.5 B=1 C=— D=3 E=1.8	A=1-2.5 B=2.5 C=— D=3 E=2.4		(ca. 30)	ca. 8 (ca. 9)	1	1.5	0	0
S190B **33** (9/20/73)	51	88 Color 0.4-0.7μm (SO-242)	310-342 (317-339)	326-327	325	310-324 328-342	1	4	Ia. (317-329) Ill. (328-339)	A=2.5 B=2.5 C=2.5 D=3 E=2.6	A=2 B=2 C=2 D=2.5 E=2.1	60- 10	ca. 10 (ca. 12)	ca. 5 (ca. 7)	2.5	2.5	1	0
S190A **44/58** (9/7/73)	28	34 Color 0.4-0.7μm (SO-356)	276-303 (?-297)	—	—	276-303	0	4	Ia. (?-297) Ill. (297-298)	A=1-3 B=1-2.5 C=2 D=3 E=2.0	A=1-3 B=1-2.5 C=2 D=3 E=2.2	15- 60	(ca. 20)	ca. 8 (ca. 10)	1-2	1-2	1-2	0
		33 Color-IR 0.5-0.88μm (2443)	Do.	—	—	Do.				A=1-2 B=2 C=2 D=2.5 E=2.0	A=0.5-2 B=2 C=2.5 D=2.5 E=2.1		(ca. 60)	ca. 10 (ca. 12)	1-2	1- 2.5	0-1	1-2
		32 B/W-IR 0.8-0.9μm (2424)	Do.	—	—	Do.				A=0.5-1 B=1.5 C=— D=2 E=1.4	A=0.5 B=0.5-1.5 C=— D=2 E=1.2		(0)	ca. 40 (ca. 60)	0- 0.5	0-1	0	1-2
		31 B/W-IR 0.7-0.8μm (2424)	Do.	—	—	Do.				A=0.5-1 B=0.5 C=— D=1.5 E=0.[illegible]	A=0.5 B=0.5-1 C=— D=1.5 E=0.9		(0)	ca. 40 (ca. 60)	0	0- 0.5	0	0.5- 1.5
		35 B/W-red 0.6-0.7μm (SO-022)	Do.	—	—	Do.				A=0.5-3 B=3 C=— D=2.5 E=2.4	A=0.5-3 B=1-3 C=— D=2.5 E=2.1		(ca. 30)	ca. 6 (ca. 7)	0.5- 1.5	1-2	0.5- 1.5	0
		36 B/W-green 0.5-0.6μm (SO-022)	Do.	—	—	Do.				A=0.5-2.5 B=0.5-2 C=— D=2.5 E=2.0	A=0.5-2 B=0.5-2 C=— D=2.5 E=1.7		(ca. 30)	ca. 9 (ca. 9)	0- 1.5	1-2	0-1	0
S190B **44/58** (9/7/73)	28	86 Color 0.4-0.7μm (SO-242)	069-107 (?-097)	—	—	069-107	0	0	Ia. (087?-097)	A=1-3 B=1-3 C=1-2.5 D=3 E=2.2	A=1-3 B=1-3 C=1-2.5 D=3 E=2.2	60	ca. 9 (ca. 10)	ca. 5 (ca. 7)	1-2	1-2	0.5	0
S190A **62** (8/5/73)	15	22 Color 0.4-0.7μm (SO-356)	228-233 (228-230)	—	228-231	232-233	0	3	Kan. (228-230)	A=1-2.5 B=1 C=1 D=1 E=1.2	A=1-2.5 B=1-2 C=1.5 D=1.5 E=1.6	60		ca. 10 (ca. 10)	1.5	1.5	0.5	0
		21 Color-IR 0.5-0.88μm (2443)	Do.	—	Do.	Do.				A=1-2 B=4 C=4 D=4 E=3.4	A=1-2 B=3.5 C=4 D=4 E=3.3			ca. 12 (ca. 12)	1.5	3	1	0
		20 B/W-IR 0.8-0.9μm (2424)	Do.	—	Do.	Do.				A=1.5 B=2.5 C=— D=3 E=2.3	A=2 B=3 C=— D=3 E=2.3			ca. 15 (ca. 40)	1	1	1	0
		19 B/W-IR 0.7-0.8μm (2424)	Do.	—	Do.	Do.				A=1 B=2 C=— D=2.5 E=1.8	A=1 B=1.5 C=— D=2.5 E=1.7			ca. 16 (ca. 37)	0.5	0.5	0	0
		23 B/W-red 0.6-0.7μm (SO-022)	Do.	—	Do.	Do.				A=3 B=2 C=— D=3 E=2.7	A=1-2.5 B=1-1.5 C=— D=1.5 E=1.5			ca. 7 (ca. 10)	1- 2.5	2	0	1
		24 B/W-green 0.5-0.6μm (SO-022)	Do.	—	Do.	Do.				A=1-2 B=1 C=— D=1 E=1.2	A=2 B=1.5-2 C=— D=2.5 E=2.1			ca. 13 (ca. 13)	1	1	0.5	0
S190B **62** (8/5/73)	15	83 Color 0.4-0.7μm (SO-242)	197-207 (197-204)	197-199 206-207	200-205	—	1	7	Kan. (197-204) Neb. (196-194)	A=2.5-4 B=2.5-4 C=2.5-4 D=4 E=3.4	A=2.5-3.5 B=2.5-3.5 C=2.5-3.5 D=3.5 E=3.1	50- 15		ca. 5 (ca. 6)	2.5- 4	3.5	1- 3.5	0

FOOTNOTES

[1]Frames listed in parenthesis are wholly or partly within the project region.
[2]Numerical rating system for photographic quality and utility for geomorphic-geographic mapping: 0 = none (nil); 1 = poor; 2 = fair; 3 = good; 4 = excellent.

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FOLDOUT FRAME 1

TOGRAPHS OF ILLINOIS, IOWA, KANSAS, MISSOURI, NEBRASKA, AND SOUTH DAKOTA (page 3 of 5)

PHOTOGRAPHIC QUALITY[2] of transparencies (3d generation) A= sharpness of detail B= contrast C= color balance D= exposure E= average (mean) quality: UNENLARGED (70 mm for S190A; 5-inch for S190B)	ENLARGED (4 X for S190A; 2 X for S190B)	ENDLAP (%)	DETECTIBILITY[3] (minimum dimension in meters): STEREO-RELIEF	ROADS	UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS[2,4]: Land-surface-form factors (slope, local relief, profile)	Vegetation/agricultural landuse characteristics	Dark vs light-colored soils	Well vs poorly drained soils	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS: Individual bands: quality and utility	GENERAL REMARKS: Summary for flight (all bands)
SKYLAB 3																
A=1-2.5 B=1-2 C=2 D=3 E=2.1	A=1-2 B=1-2 C=2 D=3 E=2.0	15-60	(ca. 20)	ca. 8 (ca. 9)	1-2.5	1-2	0.5	0	1-2.5	1-2.5	1	1-2.5		1.3	Photo quality in areas with least clouds and haze is fairly good (70 mm) to fair (enl.). Haze degrades sharpness, contrast, and color. Enl. have tiny irregular brown mottles.	Only 3 partly usable frames because of widespread clouds and dense haze. Cloud-free areas in these frames (261-263, in SE Iowa from Muscatine to ca. 100 km west of Iowa City) are variably degraded by local thin high clouds and haze, especially in the color and green bands. CIR penetrates the haze better than the color band but moderate graininess results in low sharpness of detail. B/W red band has best sharpness and best utility for GG mapping.
A=1-2 B=3 C=3 D=3 E=2.6	A=1-2 B=3.5 C=3.5 D=3.5 E=3.0		(ca. 45)	ca. 10 (ca. 11)	1-2	1-2.5	0	1	1-2	1-2	1-2.5	1-2.5		1.3	Better haze penetration than color band but very grainy, hence poor to fair sharpness of detail; otherwise, photo quality is good (both 70 mm and enl.).	
A=1 B=1.5 C=— D=3 E=1.8	A=1 B=2 C=— D=3 E=2.4		(0)	ca. 30 (ca. 40)	0.5	0.5	0	1	0.5	0.5	1-2	0.5		0.6	Poor sharpness (very grainy), especially the enl. Much less useful for GG mapping than the color and CIR bands.	
A=0.5 B=1 C=— D=2 E=1.2	A=0.5 B=1.5 C=— D=2.5 E=1.5		(0)	ca. 40 (ca. 50)	0.5	0	0	0.5	0.5	0.5	1-1.5	0.5		0.5	Very poor sharpness (extremely grainy) and poor contrast. Almost useless for GG mapping.	
A=3.5 B=2-3 C=— D=3 E=3.0	A=3.5 B=3.5 C=— D=3.5 E=3.5		(ca. 20)	ca. 6 (ca. 8)	1.5-2.5	1.5-2.5	1	0	1.5-2.5	1.5-2.5	0.5	2-3.5		1.5	Photo quality good/very good (70 mm) and very good (enl.). Most useful band for GG mapping.	
A=1-1.5 B=1 C=— D=3 E=1.8	A=1-2.5 B=2.5 C=— D=3 E=2.4		(ca. 30)	ca. 8 (ca. 9)	1	1.5	0	0	1.5	0.5	0.5	1.5-2.5		0.9	Haze much degrades contrast and sharpness, making this band of relatively little value for GG mapping. Enl. have the best contrast and sharpness.	
A=2.5 B=2.5 C=2.5 D=3 E=2.6	A=2 B=2 C=2 D=2.5 E=2.1	60-10	ca. 10 (ca. 12)	ca. 5 (ca. 7)	2.5	2.5	1	0	2.5	2.5	1.5	2.5		1.9	Only 5 frames (in SE Iowa) have areas free of clouds and dense haze; even these areas have some haze and local thin clouds that degrade sharpness, contrast, and color balance. Enl. are quite grainy and fuzzier than they should be. Endlap mostly 60%.	
A=1-3 B=1-2.5 C=2 D=3 E=2.0	A=1-3 B=1-2.5 C=2 D=3 E=2.2	15-60	(ca. 20)	ca. 8 (ca. 10)	1-2	1-2	1-2	0	1-2.5	1-2.5	0-1	1-3		1.1	See summary for flight.	100% clouds over project region, except for frames 294-297, in NE and central Iowa, which have > 70% clouds and much haze in the cloud-free areas. Essentially unusable. 60% endlap between frames 293-296; 15% between 296-297.
A=1-2 B=2 C=2 D=2.5 E=2.0	A=0.5-2 B=2 C=2.5 D=2.5 E=2.1		(ca. 60)	ca. 10 (ca. 12)	1-2	1-2.5	0-1	1-2	0.5-2	1-3.5	1-2	1-2		1.3	Do.	
A=0.5-1 B=1.5 C=— D=2 E=1.4	A=0.5 B=0.5-1.5 C=— D=2 E=1.2		(0)	ca. 40 (ca. 60)	0-0.5	0-1	0	1-2	1-2	1-3.5	1-2.5	1-3		1.2	Do.	
A=0.5-1 B=0.5 C=— D=1.5 E=0.9	A=0.5 B=0.5-1 C=— D=1.5 E=0.9		(0)	ca. 40 (ca. 60)	0	0-0.5	0	0.5-1.5	0.5-1.5	1-2.5	1-2.5	1-2		0.9	Do.	
A=0.5-3 B=3 C=— D=2.5 E=2.4	A=0.5-3 B=1-3 C=— D=2.5 E=2.1		(ca. 30)	ca. 6 (ca. 7)	0.5-1.5	1-2	0.5-1.5	0	0-1.5	0.5-1.5	0-1	1.5-3.5		0.9	Do.	
A=0.5-2.5 B=0.5-2 C=— D=2.5 E=2.0	A=0.5-2 B=0.5-2 C=— D=2.5 E=1.7		(ca. 30)	ca. 9 (ca. 9)	0-1.5	1-2	0-1	0	0-1	0-1	0-1	1.5-3.5		0.8	Do.	
A=1-3 B=1-3 C=1-2.5 D=3 E=2.2	A=1-3 B=1-3 C=1-2.5 D=3 E=2.2	60	ca. 9 (ca. 10)	ca. 5 (ca. 7)	1-2	1-2	0.5	0	1-2	1-2	1	1-3		1.3	100% clouds over project region, except for frames 090-097, in NE and central Iowa, which have > 70% clouds and much haze in cloud-free areas. Essentially unusable.	
A=1-2.5 B=1 C=1 D=1 E=1.2	A=1-2.5 B=1-2 C=1.5 D=1.5 E=1.6	60		ca. 10 (ca. 10)	1.5	1.5	0.5	0	1	0	1	3		1.3	70 mm are greatly under-exposed (too dark), which severely degrades their photo quality and utility for GG mapping. Enl. have somewhat better exposure.	70 mm tap. received cover only the area southeast from vicinity of Wichita, Kansas, and are stereoscopic; parts of only 3 frames are within the project region. Enl. received extend nearly to the NW corner of Kansas but are not stereoscopic NW of Great Bend. Most frames have few clouds, but SE from Wichita considerable haze reduces sharpness, contrast, and color balance, and heavy vegetative cover also limits utility for GG mapping.
A=1-2 B=4 C=4 D=4 E=3.4	A=1-2 B=3.5 C=4 D=4 E=3.3			ca. 12 (ca. 12)	1.5	3	1	0	1.5	2	3	2.5		1.9	Excellent photo quality except quite grainy and low sharpness.	
A=1.5 B=2.5 C=— D=3 E=2.3	A=1 B=3 C=— D=3 E=2.3			ca. 15 (ca. 40)	1	1	1	0	1	0	3	1		1.2	70 mm and enl. are very grainy and have poor sharpness of detail. Essentially useless for GG mapping, except for the larger streams, lakes, and reservoirs.	
A=1 B=2 C=— D=2.5 E=1.8	A=1 B=1.5 C=— D=2.5 E=1.7			ca. 16 (ca. 37)	0.5	0.5	0	0	1	0	2	0		1.1	Similar to above, except somewhat less contrast.	
A=? B=2 C=— D=3 E=2.7	A=1-2.5 B=1-1.5 C=— D=1.5 E=1.5			ca. 7 (ca. 10)	1-2.5	2	0	1	2.5	2	1	2.5		1.7	70 mm are good quality, somewhat grainy; enl. are much poorer quality. Haze somewhat degrades contrast and sharpness, especially SE of Hutchinson, Kansas.	
A=1-2 B=1 C=— D=1 E=1.2	A=2 B=1.5-2 C=— D=2.5 E=2.1			ca. 13 (ca. 13)	1	1	0.5	0	1	0.5	1	1.5		1.0	70 mm are severely under-exposed (dark) and haze caused much degradation of contrast and sharpness; essentially useless for GG mapping. Enl. are better exposed but also degraded by haze.	
A=2.5-4 B=2.5-4 C=2.5-4 D=4 E=3.4	A=2.5-3.5 B=2.5-3.5 C=2.5-3.5 D=3.5 E=3.1	50-15		ca. 5 (ca. 6)	2.5-4	3.5	1-3.5	0	2.5-4	2.5-4	1-2.5	4		2.8	Mostly cloud-free; generally excellent photo quality, except considerable haze SE from Wichita, Kansas reduces contrast, sharpness, and color balance. Stereoscopic coverage SE from vicinity of Great Bend, Kansas; non-stereoscopic coverage to NW limits utility for GG mapping in the NW portion.	

FOOTNOTES

...sis refer to unenlarged trans-
...renthesis apply to transparency
...eet for detailed discussion of
...s.

[4] Evaluation of utility for mapping geomorphic-geographic (GG) characteristics is based on areas in the unenlarged transparencies that are free of clouds and dense haze. A range in values is given where significant variations in atmospheric conditions and/or photographic exposure or processing occur along a flight. Commonly the utility of the enlargements is ½ to 1 rating unit lower for most characteristics.

ABBREVIATIONS

Do. = ditto
B/W = black-and-white
CIR = color infrared
GG = geomorphic-geographic
IR = infrared
enl. = enlargements
unenl. = unenlarged
mm = millimeter
NA = not applicable
tap. = transparencies

[5] See Table 5 for revised spectral ranges for B/W S190A bands.

FOLDOUT FRAME 2

TABLE I. EVALUATION CHART FOR SKYLAB PHOTOGRAPHS OF ILLINOIS, IOWA, KANSAS, MISS

SYSTEM Track/ (flight date)	PASS/ ORBIT NUMBER	ROLL NO. Band Spectral range[5] (film type)	FRAME[1] NUMBERS	CLOUD COVER 0-5%	 5-30%	 >30%	USABLE FRAMES Total no. in project area Fully	 Partly	STATE COVERAGE (frame nos.)	PHOTOGRAPHIC QUALITY[2] of transparencies (3d generation) A= sharpness of detail B= contrast C= color balance D= exposure E= average (mean) quality UNENLARGED (70 mm for S190A; 5-inch for S190B)	 ENLARGED (4 X for S190A; 2 X for S190B)	ENDLAP (%)	DETECTIBILITY[3] (minimum dimension in meters) STEREO-RELIEF	 ROADS	UTILITY FOR MAPPING KE Land-surface-form factors (slope, local relief, pro	 Vegetation/agricultu land-use characte	 Dark vs ligh	 Soil	
SKYLAB 4																			
S190A **1** (1/12/74)	82	64 Color 0.4-0.7µm (SO-356)	282-300 (284-296)	290-296	284 289	282-283 285-288	6	7	Ill. (290-296) Mo. (284-291)	A= 1-3.5 B= 1-2.5 C= — D= 1-2.5 E= 1.9	A= 1-2.5 B= 1.5-2 C= — D= 0.5-2 E= 1.6	60	(ca. 15)	ca. 12 (ca. 20)	0.5- 3	1	0	0	1-
		63 Color-IR 0.5-0.88µm (2443)	Do.	Do.	Do.	Do.				A= 1-3 B= 1-3 C= — D= 1-2.5 E= 1.9	A= 0.5-1.5 B= 1 C= — D= 0.5-1.5 E= 1.0		(ca. 15)	ca. 12 (ca. 50)	0.5- 3	1	0	0	1-
		62 B/W-IR 0.8-0.9µm (2424)	Do.	Do.	Do.	Do.				A= 1-2.5 B= 1-2.5 C= — D= 1-2.5 E= 1.7	A= 1-2 B= 1-2 C= — D= 1-2 E= 1.5		(ca. 30)	ca. 20 (ca. 40)	0.5- 2.5	0	0	0	1. 2
		61 B/W-IR 0.7-0.8µm (2424)	Do.	Do.	Do.	Do.				A= 1-1.5 B= 1 C= — D= 1 E= 1.1	A= 1 B= 1 C= — D= 0.5 E= 0.8		(ca. 60)	> 50 (> 60)	0	0	0	0	1.
		65 B/W-red 0.6-0.7µm (SO-022)	Do.	Do.	Do.	Do.				A= 1-3.5 B= 1-2.5 C= — D= 1-2.5 E= 1.9	A= 2-3.5 B= 2-3.5 C= — D= 1.5-3.5 E= 2.7		(ca. 15)	ca. 15 (ca. 15)	0.5- 3	1	0	0	3
		66 B/W-green 0.5-0.6µm (SO-022)	Do.	Do.	Do.	Do.				A= 1-3 B= 1.5-3 C= — D= 1-3 E= 2.1	A= 2-3 B= 1.5-3 C= — D= 1.5-3 E= 2.3		(ca. 15)	ca. 12 (ca. 12)	1- 2.5	1	0	0	3
S190B **1** (1/12/74)	82	92 Color 0.4-0.7µm (SO-242)	103-128 (106-125)	114-125	113, 126	103-112; 127-128	0	11	Ill. (115-125) Mo. (106-116)	A= 0.5-3 B= 1-2 C= — D= 1-2.5 E= 1.7	A= 0.5-2 B= 1.5 C= — D= 1-2 E= 1.4	60	ca. 8 (ca. 10)	ca. 10 (ca. 20)	0.5- 3	1	0	0	2. 3
S190A **19** (11/30/73)	54	52 Color 0.4-0.7µm (SO-356)	041-065 (041-061)	041-044; 063-065	—	045-061	3	5	S.D. (041-048) Neb. (043-050) Ia. (048-053) Mo. (051-058) Ill. (054-061)	A= 2.5-3.5 B= 2-3 C= 2-3 D= 2-3 E= 2.6	A= 1-3 B= 1-2.5 C= 1-3 D= 0.5-3 E= 1.9	60	(ca. 15)	ca. 8 (ca. 10)	1.5- 3.5	0.5- 3	0	0	1-
		51 Color-IR 0.5-0.88µm (2443)	Do.	Do.	—	Do.				A= 1-2.5 B= 1.5-2.5 C= 1-3 D= 1-3 E= 2.0	A= 0.5-2 B= 1-3 C= 1-3 D= 1-3 E= 1.8		(ca. 20)	ca. 12 (ca. 14)	0.5- 2	0.5- 2	0	0	0.5 2
		50 B/W-IR 0.8-0.9µm (2424)	Do.	Do.	—	Do.				A= 1.5-2 B= 1.5-2 C= — D= 1.5-3 E= 1.9	A= 2 B= 1-2.5 C= — D= 1.5-3 E= 2.0		(ca. 20)	ca. 15 (ca. 15)	0-2	0-2	0	0	0-
		49 B/W-IR 0.7-0.8µm (2424)								A= B= C= D= E=	A= B= C= D= E=								
		53 B/W-red 0.6-0.7µm (SO-022)	Do.	Do.	—	Do.				A= 1-2.5 B= 0.5-2.5 C= — D= 1-3 E= 1.7	A= 1-2.5 B= 1-3 C= — D= 1.5-3 E= 2.0		(ca. 15)	ca. 8 (ca. 10)	0-3	0-3	0	0	0-
		54 B/W-green 0.5-0.6µm (SO-022)	Do.	Do.	—	Do.				A= 1-2.5 B= 1.5-2.5 C= — D= 1-3 E= 1.7	A= 1-2.5 B= 0.5-2.5 C= — D= 1-3 E= 1.7		(ca. 12)	ca. 12 (ca. 12)	1- 2.5	1- 2.5	0	0	1- 2.
S190B **19** (11/30/73)	54	90 Color 0.4-0.7µm (SO-242)	001-038 (001-032)	001-005	—	006-032	5	6	S.D. (001-008) Neb. (005-013) Ia. (010-018) Mo. (016-026) Ill. (021-032)	A= 2.5-4 B= 1.5-3 C= 2.5-3.5 D= 2.5 E= 2.8	A= 2.5-3.5 B= 1.5-3 C= 2.5 D= 2-3 E= 2.6	60	ca. 8 (ca. 10)	ca. 5 (ca. 7)	1-4	1-3	0-1	0	1- 3.
S190A **19** (1/18/74)	85	70 Color 0.4-0.7µm (SO-356)	142-162 (138-156+)	145-153	154	155-162	7	4	S.D. (138-154) Neb. (151-156) Ia. (155-?)	A= 2-3.5 B= 2-3.5 C= 3 D= 2-3.5 E= 2.8	A= 1-2.5 B= 1-3.5 C= 3 D= 1-3.5 E= 2.3	60	(ca. 15)	ca. 7 (ca. 8)	1- 3.5	1- 3.5	0-3	0	1- 3.5
		69 Color-IR 0.5-0.88µm (2443)	Do.	Do.	Do.	Do.				A= 2-3 B= 2 C= 2 D= 2 E= 2.1	A= 1-2 B= 2 C= 2 D= 1-2 E= 1.8		(ca. 25)	ca. 10 (ca. 13)	1- 2.5	1- 2.5	0	0	1- 2.
		68 B/W-IR 0.8-0.9µm (2424)	Do.	Do.	Do.	Do.				A= 1-1.5 B= 1-3 C= — D= 1-3 E= 1.8	A= 0.5-1.5 B= 0.5-3 C= — D= 0.5-3 E= 1.5		(ca. 40)	ca. 13 (ca. 16)	0-2	1-2	0	0	0-
		67 B/W-IR 0.7-0.8µm (2424)	Do.	Do.	Do.	Do.				A= 1-1.5 B= 1-3 C= — D= 1-3 E= 1.8	A= 0.5-1.5 B= 0.5-3 C= — D= 0.5-3 E= 1.5		(ca. 40)	ca. 13 (ca. 16)	0-2	1-2	0	0	0-
		71 B/W-red 0.6-0.7µm (SO-022)	Do.	Do.	Do.	Do.				A= 2-3.5 B= 2-3 C= — D= 2-3 E= 2.6	A= 1-2.5 B= 1-3 C= — D= 1-3 E= 1.9		(ca. 15)	ca. 8 (ca. 10)	1- 3.5	1-3	0	0	1- 3.
		72 B/W-green 0.5-0.6µm (SO-022)	Do.	Do.	Do.	Do.				A= 2 B= 1.5-2 C= — D= 2 E= 1.9	A= 1-2.5 B= 1-3 C= — D= 1-3 E= 1.9		(ca. 15)	ca. 12 (ca. 12)	1-2	1	0	0	1-
S190B **19** (1/18/74)	85	92 Color 0.4-0.7µm (SO-242)	166-195 (166-180+)	166-179	180	181-195	13	2	S.D. (166-178) Neb. (175-181) Ia. (180-?)	A= 4 B= 3.5 C= 3.5 D= 3.5 E= 3.6	A= 3 B= 2.5 C= 2.5 D= 2 E= 2.5	60	ca. 8 (ca. 10)	< 5 (ca. 8)	4	3	2- 3.5	0	4

FOOTNOTES

[1] Frames listed in parenthesis are wholly or partly within the project region.
[2] Numerical rating system for photographic quality and utility for geomorphic-geographic mapping: 0 = none (nil); 1 = poor; 2 = fair; 3 = good; 4 = excellent.

[3] Numbers not in parenthesis refer to unenlarged transparencies; numbers in parenthesis apply to transparency enlargements. See last sheet for detailed discussion of detectibility measurements.

[4] Evaluation of utility for mapping geom based on areas in the unenlarged transp haze. A range in values is given where tions and/or photographic exposure or p utility of the enlargements is ½ to 1
[5] See Table 5 for revised spectral ranges for

FOLDOUT FRAME

ORIGINAL PAGE IS
OF POOR QUALITY

OTOGRAPHS OF ILLINOIS, IOWA, KANSAS, MISSOURI, NEBRASKA, AND SOUTH DAKOTA (page 4 of 5)

PHOTOGRAPHIC QUALITY[2] of transparencies (3d generation) A= sharpness of detail B= contrast C= color balance D= exposure E= average (mean) quality — UNENLARGED (70 mm for S190A; 5-inch for S190B)	ENLARGED (4 X for S190A; 2 X for S190B)	ENDLAP (%)	DETECTIBILITY[3] (minimum dimension in meters) — STEREO-RELIEF	ROADS	UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS[2,4] — Land-surface-form factors (slope, local relief, profile)	Vegetation/agricultural land-use characteristics	Dark vs light-colored soils	Well vs poorly drained soils	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS — Individual bands: quality and utility	Summary for flight (all bands)
SKYLAB 4																
A= 1-3.5 B= 1-2.5 C= — D= 1-2.5 E= 1.9	A= 1-2.5 B= 1.5-2 C= — D= 0.5-2 E= 1.6	60	(ca. 15)	ca. 12 (ca. 20)	0.5-3	1	0	0	1-3	1	0-1	2.5		1.1	Detail and contrast very good (70 mm) to good (enl.) in high-relief, least snow-covered areas in NE Missouri & W. Illinois, but over-exposure on snow-covered plains renders detail and contrast poor, especially in central and northern Illinois.	Cloud-covered from SW end to within a few miles south of Missouri River; entirely snow-covered northeast of the Missouri River. Color and CIR bands are much over-exposed in the snow-covered area; the 4 X enl. of these bands are so severely over-exposed in the snow-covered areas as to be unusable. Photo quality of B/W farther near-IR (roll 62) is good; B/W near-IR (roll 61) is badly fogged and unusable; B/W red is excellent; and B/W green is good.
A= 1-3 B= 1-3 C= — D= 1-2.5 E= 1.9	A= 0.5-1.5 B= 1 C= — D= 0.5-1.5 E= 1.0		(ca. 15)	ca. 12 (ca. 50)	0.5-3	1	0	0	1-3	1	0-1	2.5		1.1	Similar to above. Enl. are very grainy and so over-exposed on snow-covered plains as to be useless for GG mapping in these areas; enl. also have many elongate bright red spots (even outside margins of frames).	
A= 1-2.5 B= 1-2.5 C= — D= 1-2.5 E= 1.7	A= 1-2 B= 1-2 C= — D= 1-2 E= 1.5		(ca. 30)	ca. 20 (ca. 40)	0.5-2.5	0	0	0	1.5-2	0.5	0-1	1.5		0.7	Very grainy, especially enl. Detail poor on snow-covered plains, fair elsewhere.	
A= 1-1.5 B= 1 C= — D= 1 E= 1.1	A= 1 B= 1 C= — D= 0.5 E= 0.8		(ca. 60)	> 50 (> 60)	0	0	0	0	1.5	0.5	0	0.5		0.3	Badly fogged; very grainy, especially enl.; details fuzzy; nearly useless for GG mapping.	
A= 1-3.5 B= 1-2.5 C= — D= 1-2.5 E= 1.9	A= 2-3.5 B= 2-3.5 C= — D= 1.5-3.5 E= 2.7		(ca. 15)	ca. 15 (ca. 15)	0.5-3	1	0	0	3	1	0-1	2.5		1.2	Not as badly over-exposed in snow-covered areas as the color and CIR bands. Areas with least snow cover have very good sharpness and contrast. Very useful band for GG mapping.	
A= 1-3 B= 1.5-3 C= — D= 1-3 E= 2.1	A= 2-3 B= 1.5-3 C= — D= 1.5-3 E= 2.3		(ca. 15)	ca. 12 (ca. 12)	1-2.5	1	0	0	3	1	0-1	2.5		1.2	Best exposure of all bands and better contrast than usual for this band in Midwest. Almost as sharp as red band (slightly more grainy) in least snow-covered areas. About as useful as red band for GG mapping.	
A= 0.5-3 B= 1-2 C= — D= 1-2.5 E= 1.7	A= 0.5-2 B= 1.5 C= — D= 1-2 E= 1.4	60	ca. 8 (ca. 10)	ca. 10 (ca. 20)	0.5-3	1	0	0	2.5-3	1-2	0-1	1		1.1	Clouds, haze, and over-exposure limit the frames that can be used for GG mapping. Frames 107-111 (SW to central Missouri) have > 90% clouds and dense haze; 112-113 have 15-50% clouds and dense haze, 114-125 are cloud-free. Light snow cover in dissected areas in frames 112-117 enhances topographic detail, but over-exposure on snow-covered plains in 115-125 severely limits photo quality and utility for GG mapping.	
A= 2.5-3.5 B= 2-3 C= 2-3 D= 2-3 E= 2.6	A= 1-3 B= 1-2.5 C= 1-3 D= 0.5-3 E= 1.9	60	(ca. 15)	ca. 8 (ca. 10)	1.5-3.5	0.5-3	0	0	1-3	1-3	0-2.5	1-3		1.4	Best band for GG information. 70 mm frames 41-46 somewhat over-exposed for snow-covered areas and under-exposed for snow-free areas, which degrades contrast and color, although detail is excellent. Enl. of these frames are better exposed for snow-free areas but so over-exposed for snowy ones that all detail is lost; also quite grainy with tiny brown mottles.	Cloud-free over most of South Dakota (frames 041-045 have no to few clouds); SE from S. Dakota-Nebraska border mostly (60-95%) clouds and dense haze. Some snow-covered areas in South Dakota. In S.D., color and CIR bands are under-exposed (too dark) for snow-free areas and over-exposed (too light) for snowy areas; B/W red and green bands are well exposed for snow-free areas, but over-exposed for snowy areas; B/W farther near-IR band is well-exposed for snowy areas but under-exposed for snow-free ones. B/W nearer IR band (roll 49) was not received.
A= 1-2.5 B= 1.5-2.5 C= 1-3 D= 1-3 E= 2.0	A= 0.5-2 B= 1-3 C= 1-3 D= 1-3 E= 1.8		(ca. 20)	ca. 12 (ca. 14)	0.5-2	0.5-2	0	0	0.5-2	0.5-2	0-2	0.5-2.5		0.9	Like above except more grainy, especially enl. Some red specks (defects).	
A= 1.5-2 B= 1.5-2 C= — D= 1.5-3 E= 1.9	A= 2 B= 1-2.5 C= — D= 1.5-3 E= 2.0		(ca. 20)	ca. 15 (ca. 15)	0-2	0-2	0	0	0-2	0-2	0-3	0-2		0.8	70 mm and enl. quite grainy, sharpness fair; well exposed for snowy areas, under-exposed (too dark) for snow-free areas.	
A= B= C= D= E=	A= B= C= D= E=															
A= 1-2.5 B= 0.5-2.5 C= — D= 1-3 E= 1.7	A= 1-2.5 B= 1-3 C= — D= 1.5-3 E= 2.0		(ca. 15)	ca. 8 (ca. 10)	0-3	0-3	0	0	0-3	0-3	0-2	1-2		1.1	Somewhat grainy (not as sharp as most flights). Good contrast and exposure for snow-free areas, badly over-exposed for snowy areas.	
A= 1-2.5 B= 0.5-2.5 C= — D= 1-3 E= 1.7	A= 1-2.5 B= 0.5-2.5 C= — D= 1-3 E= 1.7		(ca. 12)	ca. 12 (ca. 12)	1-2.5	1-2.5	0	0	1-2.5	1-2.5	1	1-2.5		1.2	Very grainy, poor to fairly good detail; much over-exposed for snowy areas, well exposed for snow-free ones.	
A= 2.5-4 B= 1.5-3 C= 2.5-3.5 D= 2.5 E= 2.8	A= 2.5-3.5 B= 1.5-3 C= 2.5 D= 2-3 E= 2.6	60	ca. 8 (ca. 10)	ca. 5 (ca. 7)	1-4	1-3	0-1	0	1-3.5	1-3.5	0-3	2-3.5		1.9	Cloud-free over most of S.D.; mostly clouds and haze SE from S.D.-Neb. border. Unenl. tsp. have excellent detail; enl. are slightly grainy with tiny brown mottles but very good quality. Unenl. frames 001-008 are under-exposed for snow-free terrain (which degrades contrast and color) and slightly over-exposed for local snow-covered areas in frames 003-007; enl. are better exposed for snow-free terrain, somewhat over-exposed for snowy areas. Snow cover enhances topographic detail in both dissected areas and croplands.	
A= 2-3.5 B= 2-3.5 C= 3 D= 2-3.5 E= 2.8	A= 1-2.5 B= 1-3.5 C= 3 D= 1-3.5 E= 2.3	60	(ca. 15)	ca. 7 (ca. 8)	1-3.5	1-3.5	0-3	0	1-3.5	1-3.5	0-2.5	1.5-3		1.5	70 mm slightly grainy; exposure good for snow-free areas, somewhat over-exposed for snowy areas (where many details are lost). Enl. quite grainy with tiny brown mottles; well exposed for snow-free areas, but so over-exposed for snowy areas as to be useless there.	Essentially cloud-free across South Dakota to Sioux City area; farther SE is 100% clouds. Variable light snow cover in eastern S. Dakota. The light snow cover is advantageous because it accentuates many details of topography. Enl. generally so over-exposed for snowy areas as to be useless there for GG mapping. Color and red bands are the most useful.
A= 2-3 B= 2 C= 2 D= 2 E= 2.1	A= 1-2 B= 2 C= 2 D= 1-2 E= 1.8		(ca. 15)	ca. 10 (ca. 13)	1-2.5	1-2.5	0	0	1-2.5	1-2	1-3	1-2		1.3	70 mm quite grainy; too blue; somewhat over-exposed for snowy areas. Enl. very grainy, too blue; so over-exposed for snowy areas as to be useless there; well-exposed for snow-free areas. Some red spots.	
A= 1-1.5 B= 1-3 C= — D= 1-3 E= 1.8	A= 0.5-1.5 B= 0.5-3 C= — D= 0.5-3 E= 1.5		(ca. 40)	ca. 13 (ca. 16)	0-2	1-2	0	0	0-2	0-2	1-3	1		0.9	70 mm very grainy, somewhat under-exposed for snow-free areas & over-exposed for snowy areas. Enl. extremely grainy, many black mottles; so over-exposed for snowy areas as to be useless there.	
A= 1-1.5 B= 1-3 C= — D= 1-3 E= 1.8	A= 0.5-1.5 B= 0.5-3 C= — D= 0.5-3 E= 1.5		(ca. 40)	ca. 13 (ca. 16)	0-2	1-2	0	0	0-2	0-2	1-3	1		0.9	Like above.	
A= 2-3.5 B= 2-3 C= — D= 2-3 E= 2.6	A= 1-2.5 B= 1-3 C= — D= 1-3 E= 1.9		(ca. 15)	ca. 8 (ca. 10)	1-3.5	1-3	0	0	1-3.5	1-3	0-2	1-2.5		1.4	70 mm fairly sharp; exposure fair for snow, good for snow-free areas. Enl. somewhat grainy; much over-exposed for snow-covered areas.	
A= 2 B= 1.5-2 C= — D= 2 E= 1.9	A= 1-2.5 B= 1-3 C= — D= 1-3 E= 1.9		(ca. 15)	ca. 12 (ca. 12)	1-2	1	0	0	1-2	1	1	1		0.9	70 mm slightly grainy and low contrast, exposure fair for both snowy and snow-free areas. Enl. somewhat grainy; exposure and contrast good for snow-free areas, poor for snowy areas (over-exposed for these).	
A= 4 B= 3.5 C= 3.5 D= 3.5 E= 3.6	A= 3 B= 2.5 C= 2.5 D= 2 E= 2.5	60	ca. 8 (ca. 10)	< 5 (ca. 8)	4	3	2-3.5	0	4	3.5	0-3	4		2.9	Essentially cloud-free across South Dakota to Sioux City area; farther SE is 100% clouds. Variable light snow cover in eastern S. Dakota. Unenl. tsp. are very sharp with good exposure for both snowy and snow-free areas. Enl. are somewhat grainy and over-exposed (too light), which degrades color and contrast in snow-free areas and eliminates most detail in snowy areas; many scratches.	

OTNOTES

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...enthesis apply to transparency
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...s.

[4] Evaluation of utility for mapping geomorphic-geographic (GG) characteristics is based on areas in the unenlarged transparencies that are free of clouds and dense haze. A range in values is given where significant variations in atmospheric conditions and/or photographic exposure or processing occur along a flight. Commonly the utility of the enlargements is ½ to 1 rating unit lower for most characteristics.

[5] See Table 5 for revised spectral ranges for B/W S190A bands.

ABBREVIATIONS

Do.	= ditto	enl.	= enlargements
B/W	= black-and-white	unenl.	= unenlarged
CIR	= color infrared	mm	= millimeter
GG	= geomorphic-geographic	NA	= not applicable
IR	= infrared	tsp.	= transparencies

FOLDOUT FRAME 2

TABLE I. EVALUATION CHART FOR SKYLAB PHOTOGRAPHS OF ILLINOIS, IO

SYSTEM Track/ (flight date)	PASS/ ORBIT NUMBER	ROLL NO. Band Spectral range[5] (film type)	FRAME[1] NUMBERS	CLOUD COVER 0-5%	CLOUD COVER 5-30%	CLOUD COVER >30%	USABLE FRAMES Total no. in project area Fully	Partly	STATE COVERAGE (frame nos.)	PHOTOGRAPHIC QUALITY[2] of transparencies (3d generation) A= sharpness of detail B= contrast C= color balance D= exposure E= average (mean) quality UNENLARGED (70 mm for S190A; 5-inch for S190B)	ENLARGED (4 X for S190A; 2 X for S190B)	ENDLAP (%)	DETECT (minimum in m STEREO-RELIEF
SKYLAB 4													
S190A **30** (1/14/74)	83	70 Color 0.4-0.7μm (SO-356)	120-137 (122-135)	131-137	129-130	120-128	2	11	Neb. (122-130) S.D. (131-132) Ia. (133-135)	A=0-2 B=0-1 C=— D=1 E=0.8	A=0-1.5 B=0-1 C=— D=0.5 E=0.6	60	(ca. 15
		69 Color-IR 0.5-0.88μm (2443)	Do.	Do.	Do.	Do.				A=2 B=1-2.5 C=— D=2 E=2.1	A=0-1 B=0-1 C=— D=0.5 E=0.5		(ca. 15
		68 B/W-IR 0.8-0.9μm (2424)	134-137	134-137	—	—	0	2		A=1.5 B=1-2 C=— D=1.5 E=1.5	A=0.5 B=0.5-2 C=— D=2 E=1.2		(ca. 60
		67 B/W-IR 0.7-0.8μm (2424)	120-137 (122-135)	131-137	129-130	120-128	2	11		A=1.5 B=0.5-2 C=— D=1 E=1.2	A=0.5 B=0-2 C=— D=2 E=1.2		(ca. 60
		71 B/W-red 0.6-0.7μm (SO-022)	Do.	Do.	Do.	Do.				A=3 B=1-2 C=— D=2 E=2.2	A=0-2 B=0-1 C=— D=0.5 E=0.7		(ca. 15
		72 B/W-green 0.5-0.6μm (SO-022)	Do.	Do.	Do.	Do.				A=2.5 B=0-1 C=— D=1 E=1.3	A=2 B=2 C=— D=1-1.5 E=1.7		(ca. 15
S190B **30** (1/14/74)	83	93 Color 0.4-0.7μm (SO-242)	087-111 (089-106)	094-111	090-093	087-089	11	7	Neb. (089-102) S.D. (100-105) Ia. (103-106)	A=3 B=1.5 C=— D=1.5 E=2.0	A=3 B=2 C=— D=2 E=2.3	60	ca. 8 (ca. 10
S190B **58** (1/11/74)	81	92 Color 0.4-0.7μm (SO-242)	040-061 (042-061)	042-051	052-055	056-061	11	3	Kan. (042-055) Mo. (054-061)	A=2.5 B=2.5 C=— D=2 E=2.3	A=1.5-2 B=1-2 C=— D=1.5-2 E=1.7	60	< 15 (ca. 15

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FOOTNOTES

[1]Frames listed in parenthesis are wholly or partly within the project region.
[2]Numerical rating system for photographic quality and utility for geomorphic-geographic mapping: 0 = none (nil); 1 = poor; 2 = fair; 3 = good; 4 = excellent.

[3] Numbers not in parenthesis refer to unenlarged transparencies; numbers in parenthesis apply to transparency enlargements. See last sheet for detailed discussion of detectibility measurements.

[4] Evaluati
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[5] See Table 5

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, IOWA, KANSAS, MISSOURI, NEBRASKA, AND SOUTH DAKOTA (page 5 of 5)

DETECTIBILITY[3] (minimum dimension in meters)		UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS[2,4]										GENERAL REMARKS	
STEREO-RELIEF	ROADS	Land-surface-form factors (slope, local relief, profile)	Vegetation/agricultural land-use characteristics	Dark vs light-colored soils	Well vs poorly drained soils	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	Individual bands: quality and utility	Summary for flight (all bands)
(ca. 15)	ca. 10 (ca. 15)	0.5	0.5	0	0	0.5	0.5	0	1.5		0.4	70 mm and enl. both so greatly over-exposed that few details are visible (darker features); useless for GG mapping.	Entirely snow-covered. All bands are much over-exposed and have lost much detail. High sun-elevation angle also decreases information on topographic detail. Only the 70 mm CIR and B/W red bands have even slight utility for GG mapping. Some clouds and dense haze SW of North Platte, Nebraska; essentially cloud and haze-free to NE.
(ca. 15)	ca. 10 (ca. 15)	1	0.5	0	0	1	1	0	2.5		0.8	70 mm are considerably over-exposed, but less so than the color band; enl. are more over-exposed, show few details, are quite grainy, and essentially useless for GG mapping.	
(ca. 60)	ca. 20 (ca. 40)	0.5	0	0	0	0.5	0.5	0.5	1		0.4	70 mm are somewhat over-exposed, quite grainy; enl. are quite over-exposed, very grainy. (Received only 4 frames of this band.)	
(ca. 60)	ca. 35 (ca. 40)	0-0.5	0	0	0	0-0.5	0-0.5	0-0.5	1		0.3	Like above, except less contrast.	
(ca. 15)	ca. 10 (ca. 25)	0-2	0.5	0	0	0-1	0-1	0	3		0.7	70 mm are somewhat over-exposed; enl. are extremely over-exposed, have lost most detail and are useless for GG mapping.	
(ca. 15)	ca. 10 (ca. 12)	0-1	0-0.5	0	0	0-1	0-0.5	0	2.5		0.5	70 mm and enl. both much over-exposed; much detail has been lost; nearly useless.	
ca. 8 (ca. 10)	ca. 8 (ca. 8)	1-2.5	0-1	0	0	1-2.5	1-2.5	0-1	2-3		1.1	Entirely snow-covered; considerably over-exposed (but not as badly as S190A color band), which degrades sharpness and contrast. High sun-elevation angle also decreases information on topographic detail. Some thin clouds and dense haze SW of North Platte, Nebraska; essentially cloud and haze-free to NE. Enl. relatively good quality despite severe over-exposure of the master film.	

[3]Supplementary data on detectibility measurements.--

Stereorelief detectibility was determined by examining stereopairs of the transparencies under an Old Delft stereoscope (4.5 X magnification) and/or a Kern PG-2 stereoplotter (5 to 10 X magnification) and comparing the minimum discernible stereorelief on steep to moderately steep slopes with the actual relief shown on 7 1/2 to 15-minute topographic quadrangle maps. For the S190A photos, only the 4 X transparency enlargements were used because our stereoviewing equipment could not accomodate the 70 mm transparencies. For the S190B photos, both the 5-inch unenlarged transparencies and the 2 X transparency enlargements were measured.

Roads were used as a convenient means of measuring the minimum detectibility of linear features of moderately high to high contrast. They provide the best standard basis for comparison because they are the commonest easily identified linear features whose widths can be easily measured or estimated. Each SL photograph was examined under 7 to 20 X magnification to observe the narrowest roads detectible. To determine the width of the roads, ranging from private driveways to farm roads, county roads, state and federal highways and freeways, the same or similar roads were measured with a hand 20 X comparator on U-2 or WB-57 airphotos of the same or closely similar areas. This type of ground control from the airphotos eliminates inaccuracies caused by "blooming" and fuzzy definition of these relatively high-contrast features in some SL photographs (often a road that contrasts strongly with its background shows on the photos as wider than its true width). The measured road widths are restricted to the bare road surfaces and do not include side berms, ditches, or other features of the whole road right-of-way; the bare road surfaces generally contrast strongly with the adjoining vegetated terrain.

STEREO-RELIEF	ROADS	Land-surface-form factors	Vegetation/agricultural land-use	Dark vs light-colored soils	Well vs poorly drained soils	Stream order and pattern	Valley lowlands	Water surfaces	Urbanized areas		Average (mean) utility	General remarks
< 15 (ca. 15)	ca. 10 (ca. 14)	2.5	0-2	0	0	2.5	2.5	0-1	1-2		1.3	No S190A coverage received for this flight. Entirely snow-covered. Unenl. tsp. are somewhat grainy and over-exposed (degrades sharpness and contrast). Enl. have poorer sharpness and contrast and very limited utility for GG mapping. Nearly cloud-free across Kansas from near SW corner (longitude 100°) to within 50 km of the Missouri River. Near Missouri R., in NE Kansas and adjoining Missouri, frames 052-055 have 5-15% clouds and frames 056-057, 40 to 60% clouds; remainder to NE have > 60% clouds.

...aluation of utility for mapping geomorphic-geographic (GG) characteristics is ...ed on areas in the unenlarged transparencies that are free of clouds and dense ...e. A range in values is given where significant variations in atmospheric condi...ns and/or photographic exposure or processing occur along a flight. Commonly the ...lity of the enlargements is ½ to 1 rating unit lower for most characteristics.

ABBREVIATIONS

Do.	= ditto	enl.	= enlargements
B/W	= black-and-white	unenl.	= unenlarged
CIR	= color infrared	mm	= millimeter
GG	= geomorphic-geographic	NA	= not applicable
IR	= infrared	tsp.	= transparencies

...Table 5 for revised spectral ranges for B/W S190A bands.

FOLDOUT FRAME 2

quality. A range of values is given where necessary because of variations in photo quality or utility along the flight path because of variations in atmospheric conditions (haze), exposure, or photo-processing. Commonly the utility of the enlargments is 1/2 to 1 rating unit lower for most characteristics.

3.0 GENERAL SUMMARY OF THE COVERAGE, QUALITY, AND UTILITY OF PHOTOGRAPHS FROM SKYLAB MISSIONS 2, 3, AND 4

3.1 Coverage and cloud cover

About 881,000 sq km or 81% of the total area of Illinois, Iowa, Kansas, Missouri, Nebraska, and South Dakota was covered by Skylab S190A photography (Fig. 1). Unfortunately, 48% of the total number of S190A frames that lie wholly or partly within the project region have $\geq$30% cloud cover and only 47.4% have $\leq$5% clouds; of the total number of S190B frames within the project region, 44.7% have $\geq$30% cloud cover and 49.2% have $\leq$5% clouds (Table 2).

3.2 Overall summary

In general, the quality of the photos increased from the SL 2 through SL 4 missions. However, the SL 2 photos are the most useful because they were taken at the best time of year for geomorphic mapping and are nearly cloud-free. In essentially all flights, the S190B photos yield more geomorphic information than the S190A photos.

3.3 SL 2 Mission[2]

This mission provided only two passes, 6 and 7 (tracks 19 and 33, respectively) over the project region, but nevertheless, overall, the most useful photographs, covering parts of Illinois, Iowa, Missouri, Nebraska, and South Dakota. Most of the photos are of good to excellent quality and essentially cloud-free, with little haze degradation. Also, both passes were flown on June 10, 1973--still early enough in the year to profit from the croplands having been newly plowed, foliage coverage still very limited in the croplands, pastures, and woodlands, and soil-moisture conditions being nearly optimum for showing differences in soil drainage. None of the photography taken on later missions achieved so favorable a combination of circumstances for obtaining maximum information on landforms, soils, and surficial deposits.

<u>Pass/orbit 6 (track 19)</u>.--These photos are essentially cloud-free and properly exposed throughout the project region. Of the S190A multispectral photos, the unenlarged (70 mm) positive transparencies are evaluated as follows: the high-resolution color (SO 356 film) band is of excellent quality; the color-infrared band is quite grainy but otherwise of excellent quality; both B/W infrared bands are extremely grainy and very poor in sharpness of detail; the B/W red band is excellent, and the B/W green band only of fair quality. The color band provides the greatest amount of information, especially on topographic detail (land-surface form, valley lowlands, and stream order and pattern) and soil color. The graininess of the color-infrared photos somewhat reduces the information they provide on topographic detail; nevertheless, these photos show soil differences very well. The B/W red band gives sharp topographic detail, including stream alinements, but less information on soils. The B/W infrared bands are so extremely grainy and fuzzy that they yield almost no

Table 2 near here.

[2] Spectral wavelength ranges of the various film-filter combinations (here called "bands") in the S190A multispectral camera array are given in Tables 1 and 4 and section 1.2.

Table 2. Comparisons of Skylab photography of the project region:

(1) total frames received vs those wholly or partly within the project region, and

(2) frames within the project region with <5% clouds vs those with >30% clouds.

Mission/ Track	(1) Total frames received	(1) Frames wholly or partly within the project region	(2) (of frames within project region) < 5% clouds	(2) (of frames within project region) > 30% clouds
		S 190A		
SL 2, T 19	31	30	30	0
T 33	29	27	18	7
SL 3, T 1	13	11	2	9
T 30/16	8	7	0	7
T 30/44	13	6	3	2
T 33	17	11	0	10
T 44/58	28	ca. 10	0	ca. 10
T 62	6	3	3	0
SL 4, T 1	19	13	7	4
T 19 (11/30/73)	25	21	4	17
T 19 (1/18/74)	21	ca. 18	9	ca. 9
T 30	18	14	5	7
Totals	228	171*	81	82
Percentage of total frames wholly or partly within the project region			47.4	48.0

* 171 x 6 bands = 1026 total S 190A MSS photos wholly or partly within the project region.

Mission/ Track	(1) Total frames received	(1) Frames wholly or partly within the project region	(2) < 5% clouds	(2) > 30% clouds
		S 190B		
SL 2, T 19	40	39	39	0
T 33	36	33	23	8
SL 3, T 1	18	12	4	7
T 30/16	16	15	0	15
T 30/44	17	11	5	5
T 33	33	23	2	20
T 44/58	29	ca. 17	0	ca. 17
T 62	11	8	3	0
SL 4, T 1	26	20	12	7
T 19 (11/30/73)	38	32	5	27
T 19 (1/18/74)	20	ca. 17	14	ca. 3
T 30	25	18	13	3
T 58	22	19	10	6
Totals	331	264	130	118
Percentage of total frames wholly or partly within the project region			49.2	44.7

information on topographic detail; however, at this time of year they show soil-drainage differences very well. They also show well the larger water bodies (because of high contrast) but the smaller ponds and flowing creeks are not registered because of the very poor resolution. The B/W green band is the least useful because of reduced contrast and sharpness as a result of atmospheric scattering and haze degradation.

All the 4 X S190A enlargements are less sharp (fuzzier) than they should be.

The S190B unenlarged color positive transparencies are excellent quality. Their superior sharpness (because of high-resolution film SO 242) and stereorelief capability makes them especially useful for geomorphic-geographic mapping. Unfortunately, the 2X enlargements are much less useful, for they are slightly out of focus and have severe distortion (when viewed with a stereoscope or stereoplotter) for about 3/4-inch around their outer margins, indicating poor enlarger optics.

Pass/orbit 7 (track 33).--The remarks above also pertain to this track, except (1) there is considerable cloud cover across South Dakota northwest of Sioux City, and (2) eight frames of the S190A color and color-infrared bands and nine of the S190B frames (in South Dakota and Iowa) are considerably under-exposed (too dark), which impairs their contrast, color balance, and sharpness, thus reducing their utility for geomorphic-geographic mapping.

3.4 SL 3 Mission

Photos from this mission were taken at a poor time-of-year for interpreting geomorphology, soils, and surficial deposits; i.e., late in the growing season, when foliage cover was essentially at its maximum. (Flight dates range from Aug. 5 to Sept. 20, 1973.) (The B/W IR bands are essentially useless because the highly reflective foliage largely obscures any tonal differences that might be caused by variations in reflectance of soils.) The usable coverage is severely limited by extensive cloud cover on most flights. (For example, the photos taken on flight track 44/58, pass/orbit no. 28, are almost totally unusable because of nearly continuous clouds over the project region.) In addition, atmospheric haze in the cloud-free areas commonly impairs the sharpness, contrast, and color, reducing the information content of the photos. Also, in several flights, some frames are slightly to considerably underexposed (too dark) for the ground surface, which further impairs their information content. Most of the flights on this mission also were deficient in the amount of endlap of successive frames, so that they do not provide a capability for comprehensive stereoviewing.

Pass/orbit48 (track 1). --Pepper-and-salt pattern of clouds and cloud shadows over most of the project region (except near Chicago) severely limits utility for geomorphic-geologic mapping. Despite considerable atmospheric haze, the quality of the unenlarged transparencies is mostly excellent for the color (both S190A and S190B) and B/W red-band photos, fairly good for the CIR and B/W farther near-IR, and fair for the B/W nearer IR and B/W green-band photos. The color and B/W red-band photos are the most useful for geomorphic-geographic mapping, and CIR band is moderately useful, and the B/W IR and B/W green bands are nearly useless. The enlargements are all quite grainy, considerably less sharp than they should be, except the S190B 2 X enlargements, which are quite sharp and have good color. Endlap is mostly 60%, but in places changes to 15% and locally to 0% with gaps in coverage.

Pass/orbit 31 (track 30/16)--Widespread clouds limit the cloud-free coverage to parts of 3 frames (S190A) and 8 frames (S190B), mainly in eastern South Dakota. Of the S190A photos, the color band is somewhat under-exposed (too dark), the CIR band is much under-exposed, the B/W red band is well exposed; both B/W IR bands are very grainy and fuzzy, essentially useless for geomorphic mapping; the B/W green band also is useless because of poor sharpness and very low contrast caused by haze. The S190B photos were made with high resolution B/W panchromatic (3414) film and have very sharp detail, although degraded in contrast because of moderate under-exposure. The S190A 4 X enlargements are generally quite grainy; the S190B 2 X enlargements are quite sharp, although poor in contrast.

Pass/orbit 27 (track 30/44)--Cloud cover limits the wholly usable frames to 2 (S190A) and 5 (S190B), and the partly usable ones to 2 (S190A) and 1 (S190B). All the usable S190A frames are badly under-exposed in the color, CIR, B/W red, and B/W green bands (not the B/W IR bands). The S190A 4 X enlargements of the color and CIR bands are better exposed. The S190B color transparencies (both unenlarged and 2 X enlargements) are good quality and show good topographic detail. Lack of adequate endlap for stereoscopic viewing severely limits the utility of both the S190A and S190B photos for mapping landforms.

Pass/orbit 51 (track 33)--S190A: Only three frames (in Iowa) are partly usable, because of widespread clouds and dense haze. Cloud-free areas in these frames are variably degraded by haze, especially the color and B/W green bands. CIR band has better haze penetration but is very grainy. B/W farther near-IR band is very grainy, B/W nearer IR band is extremely grainy; both are essentially useless. B/W red band has best sharpness, contrast, and utility. S190B: one fully and four partly usable frames with some areas free of clouds and dense haze, but even in these areas some haze degrades contrast, sharpness, and color. Enlargements are quite grainy and fuzzier than they should be. Endlap is mainly 60% but only 10% for the western part of the usable coverage in Iowa.

Pass/orbit 28 (track 44/58)--Essentially unusable--28 S190A frames and 37 S190B frames. One hundred percent cloud cover over the project region except for four S190A frames and eight S190B frames (in NE and central Iowa), which have >70% clouds and much haze in the cloud-free areas; also, some of these frames have only 15% endlap.

Pass/orbit 15 (track 62)--S190A: Of the 70 mm transparencies received, parts of only three frames are within the project region, southeastward from the vicinity of Wichita, Kansas. These frames have few clouds but considerable haze, and have 60% endlap. We received 4 X enlargements covering not only the above area but also extending nearly to the NW corner of Kansas; however, NW of Great Bend they have only 15% endlap. The color and B/W green bands are greatly under-exposed (too dark); their enlargements are better exposed. The CIR band is quite grainy but has excellent color and contrast. The B/W red band 70 mm transparencies are good quality, though somewhat grainy; their enlargements are poor.

S190B: Coverage extends from near the NW to the SE corners of Kansas, and is mostly cloud-free but with much haze SE from the vicinity of Wichita. Excellent photo quality except where haze reduces contrast, color balance, and sharpness. Stereoscopic (60% endlap) SE from vicinity of Great Bend, nonstereoscopic (15% endlap) NW of Great Bend.

3.5 SL 4 Mission

Much coverage with few or no clouds (and also much with extensive cloud cover). Winter season--flight dates range from Nov. 30, 1973 to Jan. 18, 1974. Snow cover ranges from nil to partial to full. Color, CIR (and other S190A bands in some tracks) are generally over-exposed for snow-covered areas, and in some cases under-exposed (too dark) for snow-free areas[/]. (For Track 30

[/]Exposure problems reach their zenith in areas with patchy snow cover (for example, SL 4, T 19 (Nov. 30, 1973), frames 041-043). Exposure that is correct for snow-free terrain will over-expose the snow-covered areas, and vice-versa. A possible remedy: use an exposure about half-way between the two correct values; then, in processing the enlargements, expose one set correctly for now, the other set correctly for snow-free ground. (Unlike photos with partial cloud cover, in those with partial snow cover, both the snowy and snow-free terrain can yield important geomorphic data, if the photography is of adequate quality in each type of area.)

(pass/orbit no. 83), all S190A bands are so over-exposed as to be nearly useless.) In all tracks with snow-covered areas there are almost no shadows because of the relatively high sun-elevation angle (the photos were taken nearly at midday local time)--which is unfortunate because details of topography would have been greatly enhanced by shadowing if the photos had been taken with a low sun-elevation angle. For snow-free areas, foliage cover is minimal but fewer croplands have been plowed than in spring (SL 2 mission) and soil differences also generally are less distinct at this time of year. Some of the color photos (S190A and/or S190B unenlarged transparencies) from this mission are the sharpest of all the Skylab photos--those properly exposed for snow-free areas, especially the S190B track 19 (Jan. 18, 1974) photos. Utility of the CIR band for geomorphic mapping at this time of year is relatively poor, and that of the B/W IR bands is very poor; the B/W green band has less haze degradation and hence higher utility than it does from the other SL missions.

Pass/orbit 82 (track 1)--Mostly cloud-covered from SW end to within a few miles south of the Missouri River; mostly cloud-free but entirely snow-covered NE of Missouri River, across NE Missouri and Illinois. The color (S190A and S190B) and CIR (S190A) photos are somewhat to severely over-exposed for snow-covered areas. B/W red and green bands are well exposed for both snowy and snow-free areas and have good sharpness of detail.

Pass/orbit 54 (track 19, flown Nov. 30, 1973.--Cloud-free over most of South Dakota; 60-95% clouds and dense haze SE from South Dakota-Nebraska border. S190A: 70mm color and CIR bands are somewhat over-exposed for snowy areas and somewhat under-exposed for the snow-free areas; color band has excellent sharpness of detail. (Enlargements are very over-exposed for the snowy areas and grainy.) Other 70 mm bands range in sharpness and contrast from very poor to fairly good, and in utility for geomorphic mapping from poor to fairly good.

S190B: Sharpness of detail is excellent (unenlarged transparencies) to good (enlargements). Many frames are under-exposed (too dark) for the snow-free areas and over-exposed for the snowy areas.

Pass/orbit 85 (track 19, flown Jan. 18, 1974.--Essentially cloud-free across South Dakota, but 100% cloud cover southeastward from near Sioux City, Iowa. S190A: 70 mm color, CIR, and B/W IR bands are well-exposed for snow-free areas, but badly over-exposed for snowy ones. B/W IR bands are very grainy. B/W red band is fairly sharp and well exposed for both snowy and snow-free areas. All enlargements are very grainy and so over-exposed for the snowy areas as to be useless for geomorphic mapping in these areas.

S190B: Unenlarged transparencies are very sharp and well-exposed for both snowy and snow-free areas--about the best-quality photos obtained from Skylab. Variable light snow cover in eastern South Dakota enhances topographic detail. Enlargements are somewhat grainy and over-exposed, especially in the snowy areas.

Pass/orbit 83 (track 30)--Entirely snow-covered. Some clouds and much haze SW of North Platte, Nebraska, few to none to northeast. S190A: all bands are much over-exposed and register relatively few details; only the CIR and B/W red bands have even slight utility for geomorphic mapping. S190B: not so badly over-exposed as the S190A color band, hence of moderate utility for geomorphic mapping. Enlargements are better than usual quality.

Pass/orbit 81 (track 58)--No S190A photos, only S190B photos received. Entirely snow-covered. Mostly cloud-free from SW Kansas to within 50 km of the Missouri River; some clouds in NE Kansas and NW Missouri; 40 to >60% clouds farther to NE. Unenlarged transparencies are somewhat grainy and over-exposed and of only moderate utility for geomorphic mapping. Enlargements have poor sharpness and contrast and very limited utility.

4.0 COMPARATIVE UTILITY OF THE VARIOUS S190A MULTISPECTRAL BANDS AND OF S190B PHOTOS

4.1 General considerations

The comparative utility of the various S190A bands changes considerably with seasonal changes in vegetative cover, newly plowed land, and soil moisture. These changes are greatest for the color-infrared (CIR) and B/W IR bands but are appreciable for the other bands as well. Also, the atmospheric haze commonly present in this region causes much scattering, particularly in the color and B/W green bands, resulting in degradation of contrast, sharpness of detail, and (in the color band) hue and chroma. The amount of haze degradation varies considerably between the various flights (Table 1). It is well known that the CIR and B/W IR bands are the least affected by haze.

4.2 S190A color photos (0.4-0.7 μm)

The color photos are the best in all-around utility of the S190A multispectral array at all times of year. They furnish the most total information, in the greatest detail, because of the high resolution, spectral range, and color fidelity of the SO 356 color film. Especially advantageous for geomorphic, soil, and geologic mapping is the fact that this film-filter combination actually enhances the longer wavelengths in the visible spectrum, namely, the reddish hues. (These are mostly lost in aerial color films such as SO 397, which also has only about half the resolution of the SO 356 film.) However, the plethora of detailed information, much of it not related to geomorphology, soils, and geology, commonly is a drawback. Also these photos have relatively poor haze penetration.

4.3 S190A color-infrared (CIR) photos (0.5-0.88 μm)

These photos have good haze penetration and show differences in relief and soil mosture (soil drainage) fairly well (especially in the SL photos taken in spring) but they have fairly low spatial resolution (sharpness of detail), generally being quite grainy. They emphasize vegetation differences much better than the B/W IR bands (and, of course, any other bands). The ease with which the red-hued IR-reflective vegetation can be distinguished can be either an advantage or a disadvantage. It is an advantage where vegetation differences correspond to and reveal differences in geomorphology; in such cases the CIR photos are at least as useful as the color photos. However, where much reflective vegetation is present the strong reddish hues are distracting noise that tends to obscure other details of the landscape. Most non-geologists consider CIR photos to be most useful during the growing season--but we regard this to be the poorest time of year for landscape mapping. We also find that in winter the CIR photos are much less useful than color and B/W red photos, even in snow-free areas--neither vegetative nor soil differences are conspicuous.

4.4 B/W infrared bands (0.7-0.8 and 0.8-0.9 μm)

The two B/W infrared bands have the poorest resolution, particularly the excessively grainy SL2 photos. Thus they are relatively poor for distinguishing topographic detail, outlines of urbanized areas, and croplands from woodlands. They have good haze penetration. The larger open-water bodies generally contrast highly with adjacent terrain because of their negligible reflectance; however, the smaller streams and ponds cannot be seen because of the poor resolution. Water bodies that are very turbid or rich in algae or other vegetation may also be too reflective to be seen. Moreover, lakes and ponds commonly cannot be distinguished from cloud shadows, particularly in underexposed photos. Gross differences in soil moisture/drainage commonly show well where bare soil is exposed, as in some SL2 photos; however, where areas of leafy vegetation are present, soil differences cannot be distinguished from vegetation differences as well as they can be in CIR photos. In general, any tonal differences that are evident in either of these IR bands are most clearly evident in the farther near-IR band because of its somewhat greater contrast compared with the nearer-IR band. In winter these bands rank among the least useful bands because tonal differences caused by vegetative and soil differences are very small, even in snow-free areas.

4.5 S190A B/W red band (0.6-0.7 μm)

The B/W red band has good resolution and fair haze penetration. It shows topographic and stream-alinement details especially well, with little distracting noise; also some soil-moisture differences are shown in SL2 photos that supplement those shown on the B/W IR bands. This band is poor to fair for distinguishing water bodies. It ranks after the color and CIR bands in general utility for geomorphic mapping.

4.6 S190A B/W green band (0.5-0.6 μm)

The photos in this band generally are degraded in contrast and sharpness because of atmospheric scattering caused by the widespread atmospheric haze in this region. Scattering is much more pronounced in this spectral band than in the longer wavelengths. Consequently, this band generally has the poorest utility for geomorphic mapping.

4.7 S190B photos

The high-resolution SO 242 color film generally used in the S190B Earth Terrain Camera resulted in extraordinarily sharp photos, with good color balance, including enhancement of reddish hues (very desirable). The better photos can be enlarged more than 10 X without significant loss of detail/. Consequently,

/The 2X enlargements of S190B color photos from SL 2 are much less sharp than they should be--distinctly less sharp than the unenlarged 5-inch photos viewed under 2 X magnification. Also, when viewed under a high-quality stereoscope or a Kern stereoplotter, they have severe distortion starting about 3/4-inch in from their edges. This is not vignetting. The unenlarged S190B photos do not have this; therefore the distortion appears to be caused by poor optics in the enlarger. The 2 X enlargements from SL3 and SL4 are better quality.

the S190B photos invariably yield significantly more geomorphic information, in greater detail, than any S190A photos of a given area.

On one SL3 pass, 31, B/W high-resolution panchromatic film (SO 3414) was used. These photos have superior sharpness of detail but unfortunately those covering the only area in which they were evaluated for geomorphic mapping (the Sioux Falls test area) are badly underexposed. This, together with their limited tonal range compared with color photos (and the lack of stereoscopic coverage on this flight), severely restricts their usefulness for mapping geomorphology, soils, and geology.

5.0 SUMMARY OF QUALITY AND UTILITY OF S192 MULTISPECTRAL IMAGES

The only S192 multispectral imagery received was three scenes, taken on Passes 81 and 82 of the SL4 mission. One scene, 1,420 km long, covered parts of northeastern Kansas and northwestern Missouri; another, 1,140 km long, covered parts of northeastern Missouri and west-central Illinois; and the third, 1,140 km long, covered parts of west-central and central Illinois. All three scenes are 80 to 90% snow-covered. Table 3 gives the results of detailed evaluation of key attributes of quality and utility for the three scenes.

Each scene is represented by 12 different photo images (positive film transparencies) from 12 different spectral bands. Bands 2, 4, 5, and 6 cover the visible reflective spectral region (0.45-0.74 μm); bands 7, 8, 9, 10, 11, and 12 cover the near-infrared reflective spectral region (0.77-2.34 μm); and band 13-1 (10.07-12.68 μm) is in the middle-infrared emissive spectral region. Precise left, center, and right coordinates are printed on the margins of the images to identify the latitudinal/longitudinal location of the 1,000 scan-line near the lengthwise center of each image.

These images provide better spectral resolution, from more bands with narrower spectral ranges and over a broader spectrum, than ever previously obtained from satellite multispectral scanners for earth-resource studies. However, image quality is degraded by data-processing chatter noise, semicircular scanner noise, and random scanner-interruption lines. Semicircular scanner noise varies from slight to severe in its degrading effect, and is most severe in bands 11, 12 and 13-1 (performance problems in the 7-3 detector resulted in very poor signal-noise ratio at these long wavelengths); in these bands only the larger open-water bodies and the larger topographic features in highly dissected areas are discernible.

The images have poor sharpness of detail because of relatively coarse pixel size and because of differential resolution--resolution along the scan direction is poorer than it is perpendicular to the scan direction. This is because the distance for a detectable change is 1 to 2 pixels along the scan direction and only 1 pixel perpendicular to the scan direction. As a result, when the S192 images are magnified more than 4 times the pixels appear fuzzy with serrated edges, and those that contrast highly with adjacent ones show severe blooming.

Poor data processing has produced images deficient in subtle gray-scale differences. Photographically, all the images are overexposed and too contrasty; some are extremely so, with snow-covered areas appearing washed out and without detail. Bands 3, 7, and 8 have the best (though only fair) gray-scale discrimination and snow-covered areas show shadows in places that reveal small relief differences.

The usefulness of these images for geomorphic-geographic mapping is limited by their poor spatial resolution, noise degradation, ubiquitous snow cover (that conceals soils and surficial materials), and clouds locally. However, several bands have special attributes that somewhat enhance their utility: the IR bands (7 to 13-1) all show the larger bodies of open water much more distinctly than the bands in the visible region. Their spatial

Table 3 near here.

FOLDOUT FRAME

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OF POOR QUALITY

TABLE 3. EVALUATION CHART FOR SKYLAB S 192 MULTISPECTRAL SCANNER IMAGES (page 1

MISSION: **SL4**

SYSTEM: **S192 (MSS)**

TRACK: **58**

FLIGHT DATE: 1/11/74

PASS/ORBIT NO.: 81

GMT START: 17:35' 19.4303"

GMT STOP (est'd): 17:35' 39.9806"

SCALE OF SCENE: ca. 1:800,000

CLOUD COVER (%): 15

SNOW COVER (%): 90

DATA FOR THE 1000 SCAN TICK[1]

GMT: 17:35' 29.9689"

CO-ORDINATES (in direction of flight)

LEFT: N Lat. $39^{o}26'9.4"$
W Long. $95^{o}47'16.2"$

CENTER: N Lat. $39^{o}8'12.2"$
W Long. $95^{o}36'8.2"$

RIGHT: N Lat. $38^{o}50'15.1"$
W Long. $95^{o}25'3"$

STATE COVERAGE AND KEY GEOGRAPHIC FEATURES:

The SW to NE flight path extends from 40.6 km SW of Topeka,
20.3 km NE of the Missouri River into NW Missouri. The Miss
extends from near the south edge of St. Joseph past Atchinson
Leavenworth to near Kansas City. The Kansas River extends f
(at the south center edge of the scene) to about 35 km west
Alluvial lowlands along the Missouri River are 3.2 to 9.5 km
along the Kansas River, 3.4 to 4.8 km wide. Local relief is
in the highly dissected belts of bluffs that border both riv
attaining 75-90 m along the Missouri, but decreases upstream
Kansas River to about 45 m west of Topeka. The uplands behi
bluffs are moderately dissected with well-integrated drainag
a few relatively level interfluve plateaus.

SPECTRAL REGION	BAND MSS spectral range[3]	SDO no.	IMAGE QUALITY[2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS: Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
VISIBLE (reflective)	2 0.44-0.52 µm (blue-green)	18	A= 0-0.5 B= 0.5 C= 0.4	ca. 35	0	0.5	0-0.5	0	0.5		0.3	Severe scattering in this spectral range reduces contrast to and also degrades sharpness. Clouds cannot be discriminated Essentially useless for GG mapping.
	3 0.49-0.56 µm (green)	1	A= 1 B= 1 C= 1.0	ca. 35	1	1-1.5	0.5	0-0.5	0.5		0.7	Considerable data-processing chatter noise perpendicular to flight in NE half of scene. Poor gray-scale discrimination sharpness of detail. Clouds cannot be distinguished clearly Very poor utility.
	4 0.53-0.61 µm (yellow-green)	3	A= 1 B= 1.5 C= 1.3	ca. 30	1	1-1.5	0.5	0-0.5	0.5		0.7	Some data-processing chatter noise perpendicular to line of edge of image. Clouds not clearly discriminated from snow. discrimination poor.
	5 0.59-0.67 µm (orange)	5	A= 1 B= 1 C= 1.0	ca. 35	0.5	1	0.5	0-0.5	0.5		0.6	Pixel boundaries are very fuzzy; high-contrast ones commonly blooming. Gray-scale discrimination and contrast are poor. shadows cannot be discriminated from ground features. Open as obvious as in IR bands.
	6 0.64-0.75 µm (red)	7	A= 0-1 B= 0.5 C= 0.8	ca. 40	0	0.5	0	0-0.5	0.5-1		0.3	Gray-scale discrimination very poor (washed-out appearance); details are generally obscured, except the larger urban areas
NEAR IR (reflective)	7 0.75-0.90 µm	9	A= 1.5 B= 2 C= 1.8	ca. 30	1.5	1-2	0-1	0-1	0.5-1		1.0	Best band for image quality but utility for GG mapping is po gray-scale discrimination shows slight shadowing and enhance topographic detail in snow-covered uplands. Much data-proce noise along SE edge; semicircular scanner noise barely visibl
	8 0.90-1.08 µm	19	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5		0.8	Ground features very fuzzy; rather poor gray-scale discrimin semicircular scanner noise.
	9 1.00-1.24 µm	20	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5		0.8	Like above, except more scanner noise impairs identificatio ground features. Open water of main rivers is defined more in the visible-region bands.
	10 1.10-1.35 µm	17	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5-1		0.8	Poor sharpness of detail; blooming effect and much scanner definition of ground features. Fair discrimination of cloud (poorer than bands 11-13).
	11 1.48-1.85 µm	11	A= 0.5 B= 0-1 C= 0.8	> 35	0-0.5	0-0.5	0	0-1	0		0.2	Very poor contrast. Strong scanner noise (perhaps inherent i instrumentation related to smaller signal-noise ratio at lon lengths). Very poor definition of topographic detail (slight than band 12). Open water is clearly defined. Good discrimin clouds vs snow.
	12 2.00-2.43 µm	13	A= 0-0.5 B= 0-0.5 C= 0.5	> 35	0	0	0	0-1	0		0.1	Very poor sharpness and contrast; only very gross topograph are visible; useless for GG mapping. Clouds are clearly di from snow; open water is very evident. Much semicircular s probably due to the smaller signal-noise ratio at longer wa
MIDDLE IR (emissive)	13-1 10.20-12.50 µm	21	A= 0 B= 0-0.5 C= 0.3	ca. 40	0	0	0	0-1	0		0.1	Strong scanner noise; extremely poor contrast; no visible la features. (Thermal emissivity of snow-covered terrain prob uniform). The only features clearly evident are open-water the Missouri and Kansas Rivers. Completely useless for GG

FOOTNOTES

[1]The S 192 photo images contain short tick marks every 100 scan-lines and longer tick marks every 1000 scan-lines. Only one 1000 scan-line tick appears in each scene, near the center of the

Summary for this flight (all bands): Poor processing of the multispectral scanner digital data has res images being too contrasty and deficient in subtle gray-scale differences; also the pixels have fuzzy edges an contrast highly with adjacent ones show severe blooming. Ground resolution is poorer than that of the better images. Small towns are not visible, nor are roads narrower than about 30 m. This scene is 90% snow-covered covered. The snow obscures all information on soils and surficial materials; also the combination of a relati elevation angle and too-contrasty images has largely prevented the accentuation of topographic detail than can *result of shadowing with a low sun-elevation angle and proper gray-scale rendering.* Bands 2 and 6 show practi topographic detail from shadowing. Bands 11-12 afford good discrimination between clouds and snow; the other poor discrimination. All the IR bands afford good discrimination of the larger ice-free water bodies, notabl

ORIGINAL PAGE IS
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VALUATION CHART FOR SKYLAB S 192 MULTISPECTRAL SCANNER IMAGES (page 1 of 3)

SS)

/74

81

19.4303"

: 17:35' 39.9806"

ca. 1:800,000

15

90

DATA FOR THE 1000 SCAN TICK[1]

GMT: 17:35' 29.9689"

CO-ORDINATES (in direction of flight)

LEFT: N Lat. 39°26'9.4"
W Long. 95°47'16.2"

CENTER: N Lat. 39°8'12.2"
W Long. 95°36'8.2"

RIGHT: N Lat. 38°50'15.1"
W Long. 95°25'3"

STATE COVERAGE AND KEY GEOGRAPHIC FEATURES:

The SW to NE flight path extends from 40.6 km SW of Topeka, Kansas to 20.3 km NE of the Missouri River into NW Missouri. The Missouri River extends from near the south edge of St. Joseph past Atchinson and Leavenworth to near Kansas City. The Kansas River extends from Lawrence (at the south center edge of the scene) to about 35 km west of Topeka. Alluvial lowlands along the Missouri River are 3.2 to 9.? km wide, and along the Kansas River, 3.4 to 4.8 km wide. Local relief is greatest in the highly dissected belts of bluffs that border both rivers, attaining 75-90 m along the Missouri, but decreases upstream along the Kansas River to about 45 m west of Topeka. The uplands behind the bluffs are moderately dissected with well-integrated drainage and only a few relatively level interfluve plateaus.

UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS

	SDO no.	IMAGE QUALITY[2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces; lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
μm n)	18	A= 0-0.5 B= 0.5 C=0.4	ca. 35	0	0.5	0-0.5	0	0.5		0.3	Severe scattering in this spectral range reduces contrast to almost nil and also degrades sharpness. Clouds cannot be discriminated from snow. Essentially useless for GG mapping.
μm	1	A= 1 B= 1 C= 1.0	ca. 35	1	1-1.5	0.5	0-0.5	0.5		0.7	Considerable data-processing chatter noise perpendicular to line of flight in NE half of scene. Poor gray-scale discrimination causes poor sharpness of detail. Clouds cannot be distinguished clearly from snow. Very poor utility.
μm en)	3	A= 1 B= 1.5 C= 1.3	ca. 30	1	1-1.5	0.5	0-0.5	0.5		0.7	Some data-processing chatter noise perpendicular to line of flight on SE edge of image. Clouds not clearly discriminated from snow. Gray-scale discrimination poor.
μm	5	A= 1 B= 1 C= 1.0	ca. 35	0.5	1	0.5	0-0.5	0.5		0.6	Pixel boundaries are very fuzzy; high-contrast ones commonly show blooming. Gray-scale discrimination and contrast are poor. Cloud shadows cannot be discriminated from ground features. Open water is not as obvious as in IR bands.
μm	7	A= 0-1 B= 0.5 C= 0.8	ca. 40	0	0.5	0	0-0.5	0.5-1		0.3	Gray-scale discrimination very poor (washed-out appearance); terrain details are generally obscured, except the larger urban areas.
μm	9	A= 1.5 B= 2 C= 1.8	ca. 30	1.5	1-2	0-1	0-1	0.5-1		1.0	Best band for image quality but utility for GG mapping is poor. Fair gray-scale discrimination shows slight shadowing and enhancement of topographic detail in snow-covered uplands. Much data-processing chatter noise along SE edge; semicircular scanner noise barely visible.
μm	19	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5		0.8	Ground features very fuzzy; rather poor gray-scale discrimination; some semicircular scanner noise.
μm	20	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5		0.8	Like above, except more scanner noise impairs identification of some ground features. Open water of main rivers is defined more clearly than in the visible-region bands.
μm	17	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5-1		0.8	Poor sharpness of detail; blooming effect and much scanner noise impair definition of ground features. Fair discrimination of clouds from snow (poorer than bands 11-13).
μm	11	A= 0.5 B= 0-1 C= 0.8	> 35	0-0.5	0-0.5	0	0-1	0		0.2	Very poor contrast. Strong scanner noise (perhaps inherent in instrumentation related to smaller signal-noise ratio at longer wavelengths). Very poor definition of topographic detail (slightly better than band 12). Open water is clearly defined. Good discrimination of clouds vs snow.
μm	13	A= 0-0.5 B= 0-0.5 C= 0.5	> 35	0	0	0	0-1	0		0.1	Very poor sharpness and contrast; only very gross topographic features are visible; useless for GG mapping. Clouds are clearly distinguished from snow; open water is very evident. Much semicircular scanner noise, probably due to the smaller signal-noise ratio at longer wavelengths.
μm	21	A= 0 B= 0-0.5 C= 0.3	ca. 40	0	0	0	0-1	0		0.1	Strong scanner noise; extremely poor contrast; no visible landform features. (Thermal emissivity of snow-covered terrain probably was nearly uniform). The only features clearly evident are open-water reaches of the Missouri and Kansas Rivers. Completely useless for GG mapping.

NOTES

images contain
s every 100 scan-
r tick marks every
. Only one 1000
appears in each

Summary for this flight (all bands): Poor processing of the multispectral scanner digital data has resulted in the images being too contrasty and deficient in subtle gray-scale differences; also the pixels have fuzzy edges and those that contrast highly with adjacent ones show severe blooming. Ground resolution is poorer than that of the better Landsat-1 images. Small towns are not visible, nor are roads narrower than about 30 m. This scene is 90% snow-covered and 15% cloud-covered. The snow obscures all information on soils and surficial materials; also the combination of a relatively high sun-elevation angle and too-contrasty images has largely prevented the accentuation of topographic detail than can occur as a result of shadowing with a low sun-elevation angle and proper gray-scale rendering. Bands 2 and 6 show practically no topographic detail from shadowing. Bands 11-12 afford good discrimination between clouds and snow; the other bands, only

SNOW COVER (%): 90

SPECTRAL REGION	BAND MSS spectral range[3]	SDO no.	IMAGE QUALITY A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
VISIBLE (reflective)	2 0.44-0.52 μm (blue-green)	18	A= 0-0.5 B= 0.5 C= 0.4	ca. 35	0	0.5	0-0.5	0	0.5		0.3	Severe scattering in this spectral range reduces contrast and also degrades sharpness. Clouds cannot be discrimina Essentially useless for GG mapping.
	3 0.49-0.56 μm (green)	1	A= 1 B= 1 C= 1.0	ca. 35	1	1-1.5	0.5	0-0.5	0.5		0.7	Considerable data-processing chatter noise perpendicular flight in NE half of scene. Poor gray-scale discriminati sharpness of detail. Clouds cannot be distinguished clea Very poor utility.
	4 0.53-0.61 μm (yellow-green)	3	A= 1 B= 1.5 C= 1.3	ca. 30	1	1-1.5	0.5	0-0.5	0.5		0.7	Some data-processing chatter noise perpendicular to line edge of image. Clouds not clearly discriminated from snow. discrimination poor.
	5 0.59-0.67 μm (orange)	5	A= 1 B= 1 C= 1.0	ca. 35	0.5	1	0.5	0-0.5	0.5		0.6	Pixel boundaries are very fuzzy; high-contrast ones commo blooming. Gray-scale discrimination and contrast are poo shadows cannot be discriminated from ground features. Op as obvious as in IR bands.
	6 0.64-0.75 μm (red)	7	A= 0-1 B= 0.5 C= 0.8	ca. 40	0	0.5	0	0-0.5	0.5-1		0.3	Gray-scale discrimination very poor (washed-out appearanc details are generally obscured, except the larger urban ar
NEAR IR (reflective)	7 0.75-0.90 μm	9	A= 1.5 B= 2 C= 1.8	ca. 30	1.5	1-2	0-1	0-1	0.5-1		1.0	Best band for image quality but utility for GG mapping is gray-scale discrimination shows slight shadowing and enha topographic detail in snow-covered uplands. Much data-pr noise along SE edge; semicircular scanner noise barely vis
	8 0.90-1.08 μm	19	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5		0.8	Ground features very fuzzy; rather poor gray-scale discri semicircular scanner noise.
	9 1.00-1.24 μm	20	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5		0.8	Like above, except more scanner noise impairs identifica ground features. Open water of main rivers is defined mo in the visible-region bands.
	10 1.10-1.35 μm	17	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5-1		0.8	Poor sharpness of detail; blooming effect and much scanne definition of ground features. Fair discrimination of cl (poorer than bands 11-13).
	11 1.48-1.85 μm	11	A= 0.5 B= 0-1 C= 0.8	> 35	0-0.5	0-0.5	0	0-1	0		0.2	Very poor contrast. Strong scanner noise (perhaps inheren instrumentation related to smaller signal-noise ratio at lengths). Very poor definition of topographic detail (sli than band 12). Open water is clearly defined. Good discri clouds vs snow.
	12 2.00-2.43 μm	13	A= 0-0.5 B= 0-0.5 C= 0.5	> 35	0	0	0	0-1	0		0.1	Very poor sharpness and contrast; only very gross topogr are visible; useless for GG mapping. Clouds are clearly from snow; open water is very evident. Much semicircula probably due to the smaller signal-noise ratio at longer
MIDDLE IR (emissive)	13-1 10.20-12.50 μm	21	A= 0 B= 0-0.5 C= 0.3	ca. 40	0	0	0	0-1	0		0.1	Strong scanner noise; extremely poor contrast; no visibl features. (Thermal emissivity of snow-covered terrain p uniform). The only features clearly evident are open-wa the Missouri and Kansas Rivers. Completely useless for

FOOTNOTES

[1]The S 192 photo images contain short tick marks every 100 scan-lines and longer tick marks every 1000 scan-lines. Only one 1000 scan-line tick appears in each scene, near the center of the border of the scene.

[2]Numerical rating system for image quality and utility for geomorphic-geographic mapping: 0 = none (nil); 1 = poor; 2 = fair; 3 = good; 4 = excellent.

ABBREVIATIONS

GG = geomorphic-geographic
GMT = Greenwich mean time
IR = infrared
MSS = multispectral scanner
SDO = scientific data output
μm = micrometer

<u>Summary for this flight (all bands):</u> Poor processing of the multispectral scanner digital data has images being too contrasty and deficient in subtle gray-scale differences; also the pixels have fuzzy edges contrast highly with adjacent ones show severe blooming. Ground resolution is poorer than that of the bett images. Small towns are not visible, nor are roads narrower than about 30 m. This scene is 90% snow-cover covered. The snow obscures all information on soils and surficial materials; also the combination of a rel elevation angle and too-contrasty images has largely prevented the accentuation of topographic detail than result of shadowing with a low sun-elevation angle and proper gray-scale rendering. Bands 2 and 6 show pra topographic detail from shadowing. Bands 11-12 afford good discrimination between clouds and snow; the ot poor discrimination. All the IR bands afford good discrimination of the larger ice-free water bodies, nota the Missouri and Kansas Rivers.

Semicircular electronic scanner noise is present in all bands, and is so pronounced in bands 11-13 tha but the grosser features. Data-processing chatter noise (vertical lines) is present in bands 3, 4, and 7. bands 3, 4, 5, 7, 8, 9, and 10 are approximately equal in quality. Band 7 is the best band in the group, b utility of all bands for GG mapping is poor; bands 2, 6, and 11-13 are useless or nearly useless.

<u>Comparison with Skylab photographs:</u> No S190A multispectral photos were received for this flight color photos. Although the unenlarged S190B photos are somewhat grainy and over-exposed (resulting in de sharpness and contrast), they show much more topographic detail than even the best band (7) of S192 . Roa about 10 m can be distinguished on the photos, as well as stereorelief of somewhat less than 15 m.

<u>Comparison with Landsat-1 MSS images:</u> Landsat-1 snow-covered scenes of northeastern Kansas (bands 5 and 16340, Dec. 17, 1972; 1201-16341, Feb. 9, 1973; and 1202-16395, Feb. 10, 1973) were used for comparison wi images. All the Landsat-1 images are superior in gray-scale discrimination, although rather poor in contr show topographic details more clearly (such as valley-lowland boundaries, local relief of uplands, meander lakes); also, small towns are visible and details of field patterns and boundaries are much clearer; roads 10-15 m can be distinguished on the Landsat-1 images (vs ca. 30 m in band 7 of S192).

[3]See Table 5 for revised spectral ranges.

FOLDOUT FRAME

	SDO no.	IMAGE QUALITY A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
m)	18	A= 0-0.5 B= 0.5 C= 0.4	ca. 35	0	0.5	0-0.5	0	0.5		0.3	Severe scattering in this spectral range reduces contrast to almost nil and also degrades sharpness. Clouds cannot be discriminated from snow. Essentially useless for GG mapping.
m	1	A= 1 B= 1 C= 1.0	ca. 35	1	1-1.5	0.5	0-0.5	0.5		0.7	Considerable data-processing chatter noise perpendicular to line of flight in NE half of scene. Poor gray-scale discrimination causes poor sharpness of detail. Clouds cannot be distinguished clearly from snow. Very poor utility.
m n)	3	A= 1 B= 1.5 C= 1.3	ca. 30	1	1-1.5	0.5	0-0.5	0.5		0.7	Some data-processing chatter noise perpendicular to line of flight on SE edge of image.Clouds not clearly discriminated from snow. Gray-scale discrimination poor.
m	5	A= 1 B= 1 C= 1.0	ca. 35	0.5	1	0.5	0-0.5	0.5		0.6	Pixel boundaries are very fuzzy; high-contrast ones commonly show blooming. Gray-scale discrimination and contrast are poor. Cloud shadows cannot be discriminated from ground features. Open water is not as obvious as in IR bands.
m	7	A= 0-1 B= 0.5 C= 0.8	ca. 40	0	0.5	0	0-0.5	0.5-1		0.3	Gray-scale discrimination very poor (washed-out appearance); terrain details are generally obscured, except the larger urban areas.
m	9	A= 1.5 B= 2 C=1.8	ca. 30	1.5	1-2	0-1	0-1	0.5-1		1.0	Best band for image quality but utility for GG mapping is poor. Fair gray-scale discrimination shows slight shadowing and enhancement of topographic detail in snow-covered uplands. Much data-processing chatter noise along SE edge;semicircular scanner noise barely visible.
m	19	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5		0.8	Ground features very fuzzy; rather poor gray-scale discrimination; some semicircular scanner noise.
m	20	A= 1 B= 1.5 C=1.3	ca. 35	1	1-1.5	0.5	0-1	0.5		0.8	Like above, except more scanner noise impairs identification of some ground features. Open water of main rivers is defined more clearly than in the visible-region bands.
m	17	A= 1 B= 1.5 C= 1.3	ca. 35	1	1-1.5	0.5	0-1	0.5-1		0.8	Poor sharpness of detail; blooming effect and much scanner noise impair definition of ground features. Fair discrimination of clouds from snow (poorer than bands 11-13).
m	11	A= 0.5 B= 0-1 C=0.8	> 35	0-0.5	0-0.5	0	0-1	0		0.2	Very poor contrast. Strong scanner noise (perhaps inherent in instrumentation related to smaller signal-noise ratio at longer wavelengths). Very poor definition of topographic detail (slightly better than band 12). Open water is clearly defined. Good discrimination of clouds vs snow.
m	13	A= 0-0.5 B= 0-0.5 C= 0.5	> 35	0	0	0	0-1	0		0.1	Very poor sharpness and contrast; only very gross topographic features are visible; useless for GG mapping. Clouds are clearly distinguished from snow; open water is very evident. Much semicircular scanner noise, probably due to the smaller signal-noise ratio at longer wavelengths.
m	21	A= 0 B= 0-0.5 C= 0.3	ca. 40	0	0	0	0-1	0		0.1	Strong scanner noise; extremely poor contrast; no visible landform features. (Thermal emissivity of snow-covered terrain probably was nearly uniform). The only features clearly evident are open-water reaches of the Missouri and Kansas Rivers. Completely useless for GG mapping.

NOTES

images contain
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Summary for this flight (all bands): Poor processing of the multispectral scanner digital data has resulted in the images being too contrasty and deficient in subtle gray-scale differences; also the pixels have fuzzy edges and those that contrast highly with adjacent ones show severe blooming. Ground resolution is poorer than that of the better Landsat-1 images. Small towns are not visible, nor are roads narrower than about 30 m. This scene is 90% snow-covered and 15% cloud-covered. The snow obscures all information on soils and surficial materials; also the combination of a relatively high sun-elevation angle and too-contrasty images has largely prevented the accentuation of topographic detail than can occur as a result of shadowing with a low sun-elevation angle and proper gray-scale rendering. Bands 2 and 6 show practically no topographic detail from shadowing. Bands 11-12 afford good discrimination between clouds and snow; the other bands, only poor discrimination. All the IR bands afford good discrimination of the larger ice-free water bodies, notably those along the Missouri and Kansas Rivers.

Semicircular electronic scanner noise is present in all bands, and is so pronounced in bands 11-13 that it obscures all but the grosser features. Data-processing chatter noise (vertical lines) is present in bands 3, 4, and 7. The images from bands 3, 4, 5, 7, 8, 9, and 10 are approximately equal in quality. Band 7 is the best band in the group, but the general utility of all bands for GG mapping is poor; bands 2, 6, and 11-13 are useless or nearly useless.

Comparison with Skylab photographs: No S190A multispectral photos were received for this flight, only S190B color photos. Although the unenlarged S190B photos are somewhat grainy and over-exposed (resulting in degradation of sharpness and contrast), they show much more topographic detail than even the best band (7) of S192. Roads as narrow as about 10 m can be distinguished on the photos, as well as stereorelief of somewhat less than 15 m.

Comparison with Landsat-1 MSS images: Landsat-1 snow-covered scenes of northeastern Kansas (bands 5 and 6 of frames 1147-16340, Dec. 17, 1972; 1201-16341, Feb. 9, 1973; and 1202-16395, Feb. 10, 1973) were used for comparison with the S192 images. All the Landsat-1 images are superior in gray-scale discrimination, although rather poor in contrast; they also show topographic details more clearly (such as valley-lowland boundaries, local relief of uplands, meander scars and oxbow lakes); also, small towns are visible and details of field patterns and boundaries are much clearer; roads as narrow as 10-15 m can be distinguished on the Landsat-1 images (vs ca. 30 m in band 7 of S192).

[3] See Table 5 for revised spectral ranges.

TABLE 3. EVALUATION CHART FOR SKYLAB S 192 MULTISPECTRAL SCANNER IMAGES (page 2

MISSION: **SL4**

SYSTEM: **S192 (MSS)**

TRACK: **1**

FLIGHT DATE: 1/12/74

PASS/ORBIT NO.: 82

GMT START: 16:52' 46.4482"

GMT STOP (est'd): 16:53' 2.9938"

SCALE OF SCENE: ca. 1:800,000

CLOUD COVER (%): 1 (thin clouds near Mississippi River near NW edge of scene)

SNOW COVER (%): 80

DATA FOR THE 1000 SCAN TICK[1]

GMT: 16:52' 56.9868"

CO-ORDINATES (in direction of flight)

LEFT: N Lat. 39°25'6" W Long. 91°5'21"

CENTER: N Lat. 39°7'28" W Long. 90°53'17.6"

RIGHT: N Lat. 38°49'50" W Long. 90°42'9.1"

STATE COVERAGE AND KEY GEOGRAPHIC FEATURES:

The SW to NE flight path extends from 6 km SW of New Floren to 5.7 km NE of Carrollton, Illinois. The Illinois River e 8.8 km north of Montezuma, Ill. to its confluence with the River at the south edge of the image. The Mississippi Rive to within 2 km of Louisiana, Mo. on the north. The Missouri the SW part of the scene for 13.5 km. Alluvial lowlands al Illinois River are 4.5 km to 6.5 km wide, along the Mississ 6 km to 10 km wide, and along the Missouri River 5.7 km to Highly dissected zones border these rivers, with local rel 130 m along the Missouri, and 90 m (on the north) to 105 m along the Illinois and Mississippi Rivers. Uplands behind are moderately dissected with well-integrated drainage, exc several wide, relatively level interfluve plateaus, both eas the Mississippi.

SPECTRAL REGION	BAND MSS spectral range[3]	SDO no.	IMAGE QUALITY[2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS: Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
VISIBLE (reflective)	2 0.44-0.52 μm (blue-green)	18	A= 0.5-1 B= 0.5-1.5 C= 0.9	ca. 30	0-1	0-1	0-1	0-1	0.5-1		0.6	Poor cloud-snow discrimination. Thin clouds near center of edge blur ground detail. Much loss of contrast and sharpne because of scattering. Over-exposed and washed-out in snow Nearly useless for GG mapping.
	3 0.49-0.56 μm (green)	1	A= 1.5 B= 1.5-2 C= 1.6	ca. 25	1-2	1-2	0.5-1.5	0-1	1		1.1	Fair gray-scale discrimination and utility for GG mapping. semicircular scanner-interruption lines.
	4 0.53-0.61 μm (yellow-green)	3	A= 1.5 B= 1-2 C=1.5	ca. 25	1-2	1-2	0.5-1.5	0.5	1		1.1	Field patterns and other features on the Illinois and Missis alluvial lowlands are fairly well defined. Quality and util band are comparable with bands 7, 8, and 9. Several semici interruption lines.
	5 0.59-0.67 μm (orange)	5	A=1.5 B=0.5-2 C= 1.4	ca. 25	0.5-2	0-2	0.5-1.5	0.5	1		1.0	Somewhat overexposed. Gray-scale discrimination is fair in areas but very poor in snowy areas. Semicircular scanner-i lines present.
	6 0.64-0.75 μm (red)	7	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 35	0-1	0-1	0-1	0.5	0.5-1		0.6	Severely overexposed and too contrasty. Gray-scale discrim (washed-out) in snow-covered areas.
NEAR IR (reflective)	7 0.75-0.90 μm	9	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5-1	0.5-1		1.1	Poor to fair contrast, gray-scale discrimination, and utili mapping. Open-water discrimination better than in visible Several prominent semicircular scanner-interruption lines.
	8 0.90-1.08 μm	19	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5-1	1		1.2	Poor to fair gray-scale discrimination. Open water of the stands out better than in the visible spectral range.
	9 1.00-1.24 μm	20	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	1	0.5-1	1		1.2	Gray-scale discrimination poor to fair. Good penetration o clouds improves discrimination of terrain detail in the clo One very prominent semicircular scanner-interruption line. darkening in SW corner probably related to semicircular sca
	10 1.10-1.35 μm	17	A=1-1.5 B=1-2 C= 1.4	ca. 30	1-2	1-2	1	0.5-1	0.5-1		1.1	Gray-scale discrimination and contrast is poor to fair. Ut mapping nearly same as band 8 and 9. Distinct semicircular over entire image; anomalous darkening in SW corner.
	11 1.48-1.85 μm	11	A=0.5 B=0.5-1 C= 0.6	ca. 30	0-1	0-1	0-0.5	1-2	0		0.6	Poor gray-scale discrimination. Some topographic [illegible] vis dissected areas. Open water very clearly defined. Quality [illegible] than band 12 but nearly useless for GG mapping. Strong sem scanner noise (probably related to smaller signal-noise rat longer wavelength.)
	12 2.00-2.43 μm	13	A=0-0.5 B=0.5 C= 0.4	ca. 35	0-0.5	0-0.5	0-0.5	1	0		0.4	Very poor contrast and sharpness of detail. A few topograp are seen in the highly dissected areas. Open water not as defined as in band 11. Very strong scanner noise, similar and 13-1. Useless for GG mapping.
MIDDLE IR (emissive)	13-1 10.20-12.50 μm	21	A=0 B=0-0.5 C= 0.1	ca. 35	0	0	0	1-2	0		0.3	Very strong semicircular scanner noise; NW half [illegible] than SE half. Very poor gray-scale discrimination. Hig[illegible] bluffs along the Illinois, Mississippi and Missouri Rivers visible. Larger open-water bodies are as distinct as in ba Useless for GG mapping.

FOOTNOTES

[1]The S 192 photo images contain short tick marks every 100 scan-lines and longer tick marks every 1000 scan-lines. Only one 1000 scan-line tick appears in each scene, near the center of the border of the scene.

Summary for this flight (all bands): Poor processing has resulted in images deficient in subtle gray- differences. At more than 4X magnification, pixels begin to fuzz and show serrated edges and those that con with adjacent ones show severe blooming. For this reason, spatial resolution is somewhat poorer than the bet images; however, on the sharper S192 images, small towns are visible and roads as narrow as 25 m. The 80% s obscures information on soils and surficial materials. In the bands with better gray-scale discrimination, s topographic features show by shadowing, even though the sun-elevation angle is relatively high. Thin cloud o Mississippi River near NW edge of the scene blurs ground features in the shorter wavelength bands, especially the IR bands penetrate haze and thin clouds well, and also afford sharp discrimination of the larger ice-free such as those along the Illinois, Mississippi, and Missouri Rivers. Random semicircular scanner-interruption present in all bands. Scanner noise is evident over part or all of bands 9-13 and is so strong in bands 11-1

EVALUATION CHART FOR SKYLAB S 192 MULTISPECTRAL SCANNER IMAGES (page 2 of 3)

ISS)

12/74

82

' 46.4482"

: 16:53' 2.9933"

ca. 1:800,000

I (thin clouds near Mississippi River near NW edge of scene)

80

DATA FOR THE 1000 SCAN TICK[1]

GMT: 16:52' 56.9868"

CO-ORDINATES (in direction of flight)

LEFT: N Lat. 39°25'6" W Long. 91°5'21"

CENTER: N Lat. 39°7'28" W Long. 90°53'17.6"

RIGHT: N Lat. 38°49'50" W Long. 90°42'9.1"

STATE COVERAGE AND KEY GEOGRAPHIC FEATURES:

The SW to NE flight path extends from 6 km SW of New Florence, Missouri to 5.7 km NE of Carrollton, Illinois. The Illinois River extends from 8.8 km north of Montezuma, Ill. to its confluence with the Mississippi River at the south edge of the image. The Mississippi River reaches to within 2 km of Louisiana, Mo. on the north. The Missouri River crosses the SW part of the scene for 13.5 km. Alluvial lowlands along the Illinois River are 4.5 km to 6.5 km wide, along the Mississippi River, 6 km to 10 km wide, and along the Missouri River 5.7 km to 7.3 km wide. Highly dissected zones border these rivers, with local relief of about 130 m along the Missouri, and 90 m (on the north) to 105 m (on the south) along the Illinois and Mississippi Rivers. Uplands behind the bluffs are moderately dissected with well-integrated drainage, except for several wide, relatively level interfluve plateaus, both east and west of the Mississippi.

	SDO no.	IMAGE QUALITY[2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS: Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
µm n)	18	A= 0.5-1 B= 0.5-1.5 C= 0.9	ca. 30	0-1	0-1	0-1	0-1	0.5-1		0.6	Poor cloud-snow discrimination. Thin clouds near center of northern edge blur ground detail. Much loss of contrast and sharpness of detail because of scattering. Over-exposed and washed-out in snow-covered areas. Nearly useless for GG mapping.
µm	1	A= 1.5 B= 1.5-2 C= 1.6	ca. 25	1-2	1-2	0.5-1.5	0-1	1		1.1	Fair gray-scale discrimination and utility for GG mapping. Some random semicircular scanner-interruption lines.
µm en)	3	A= 1.5 B= 1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5	1		1.1	Field patterns and other features on the Illinois and Mississippi River alluvial lowlands are fairly well defined. Quality and utility of this band are comparable with bands 7, 8, and 9. Several semicircular scanner-interruption lines.
µm	5	A=1.5 B=0.5-2 C= 1.4	ca. 25	0.5-2	0-2	0.5-1.5	0.5	1		1.0	Somewhat overexposed. Gray-scale discrimination is fair in snow-free areas but very poor in snowy areas. Semicircular scanner-interruption lines present.
µm	7	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 35	0-1	0-1	0-1	0.5	0.5-1		0.6	Severely overexposed and too contrasty. Gray-scale discrimination poor (washed-out) in snow-covered areas.
µm	9	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5-1	0.5-1		1.1	Poor to fair contrast, gray-scale discrimination, and utility for GG mapping. Open-water discrimination better than in visible bands. Several prominent semicircular scanner-interruption lines.
µm	19	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5-1	1		1.2	Poor to fair gray-scale discrimination. Open water of the major rivers stands out better than in the visible spectral range.
µm	20	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	1	0.5-1	1		1.2	Gray-scale discrimination poor to fair. Good penetration of haze and clouds improves discrimination of terrain detail in the clouded areas. One very prominent semicircular scanner-interruption line. Anomalous darkening in SW corner probably related to semicircular scanner noise.
µm	17	A=1-1.5 B=1-2 C= 1.4	ca. 30	1-2	1-2	1	0.5-1	0.5-1		1.1	Gray-scale discrimination and contrast is poor to fair. Utility for GG mapping nearly same as band 8 and 9. Distinct semicircular scanner noise over entire image; anomalous darkening in SW corner.
µm	11	A=0.5 B=0.5-1 C= 0.6	ca. 30	0-1	0-1	0-0.5	1-2	0		0.6	Poor gray-scale discrimination. Some topographic detail visible in highly dissected areas. Open water very clearly defined. Quality somewhat better than band 12 but nearly useless for GG mapping. Strong semicircular scanner noise (probably related to smaller signal-noise ratio at this longer wavelength.)
µm	13	A=0-0.5 B=0.5 C= 0.4	ca. 35	0-0.5	0-0.5	0-0.5	1	0		0.4	Very poor contrast and sharpness of detail. A few topographic features are seen in the highly dissected areas. Open water not as clearly defined as in band 11. Very strong scanner noise, similar to bands 11 and 13-1. Useless for GG mapping.
µm	21	A=0 B=0-0.5 C= 0.1	ca. 35	0	0	0	1-2	0		0.3	Very strong semicircular scanner noise; NW half of image is much darker than SE half. Very poor gray-scale discrimination. Highly dissected bluffs along the Illinois, Mississippi and Missouri Rivers are faintly visible. Larger open-water bodies are as distinct as in band 11. Useless for GG mapping.

NOTES

images contain s every 100 scan- tick marks every . Only one 1000 appears in each center of the cene.

Summary for this flight (all bands): Poor processing has resulted in images deficient in subtle gray-scale differences. At more than 4X magnification, pixels begin to fuzz and show serrated edges and those that contrast highly with adjacent ones show severe blooming. For this reason, spatial resolution is somewhat poorer than the better Landsat-1 images; however, on the sharper S192 images, small towns are visible and roads as narrow as 25 m. The 80% snow cover obscures information on soils and surficial materials. In the bands with better gray-scale discrimination, some subtle topographic features show by shadowing, even though the sun-elevation angle is relatively high. Thin cloud cover near the Mississippi River near NW edge of the scene blurs ground features in the shorter wavelength bands, especially band 2. All the IR bands penetrate haze and thin clouds well, and also afford sharp discrimination of the larger ice-free water bodies, such as those along the Illinois, Mississippi, and Missouri Rivers. Random semicircular scanner-interruption lines are present in all bands. Scanner noise is evident over part or all of bands 9-13 and is so strong in bands 11-13 as to obscure

SPECTRAL REGION	BAND MSS spectral range[3]	SDO no.	IMAGE QUALITY[2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	Land-surface form factors, (slope, local relief, pattern)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
VISIBLE (reflective)	2 0.44-0.52 μm (blue-green)	18	A= 0.5-1 B= 0.5-1.5 C= 0.9	ca. 30	0-1	0-1	0-1	0-1	0.5-1		0.6	Poor cloud-snow discrimination. Thin clouds near center o edge blur ground detail. Much loss of contrast and sharpn because of scattering. Over-exposed and washed-out in sno Nearly useless for GC mapping.
	3 0.49-0.56 μm (green)	1	A= 1.5 B= 1.5-2 C= 1.6	ca. 25	1-2	1-2	0.5-1.5	0-1	1		1.1	Fair gray-scale discrimination and utility for GG mapping. semicircular scanner-interruption lines.
	4 0.53-0.61 μm (yellow-green)	3	A= 1.5 B= 1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5	1		1.1	Field patterns anu other features on the Illinois and Miss alluvial lowlands are fairly well defined. Quality and ut band are comparable with bands 7, 8, and 9. Several semic interruption lines.
	5 0.59-0.67 μm (orange)	5	A=1.5 B=0.5-2 C= 1.4	ca. 25	0.5-2	0-2	0.5-1.5	0.5	1		1.0	Somewhat overexposed. Gray-scale discrimination is fair i areas but very poor in snowy areas. Semicircular scanner- lines present.
	6 0.64-0.75 μm (red)	7	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 35	0-1	0-1	0-1	0.5	0.5-1		0.6	Severely overexposed and too contrasty. Gray-scale discri (washed-out) in snow-covered areas.
NEAR IR (reflective)	7 0.75-0.90 μm	9	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5-1	0.5-1		1.1	Poor to fair contrast, gray-scale discrimination, and util mapping. Open-water discrimination better than in visible Several prominent semicircular scanner-interruption lines.
	8 0.90-1.08 μm	19	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5-1	1		1.2	Poor to fair gray-scale discrimination. Open water of the stands out better than in the visible spectral range.
	9 1.00-1.24 μm	20	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	1	0.5-1	1		1.2	Gray-scale discrimination poor to fair. Good penetration c clouds improves discrimination of terrain detail in the cl One very prominent semicircular scanner-interruption line. darkening in SW corner probably related to semicircular sc
	10 1.10-1.35 μm	17	A=1-1.5 B=1-2 C= 1.4	ca. 30	1-2	1-2	1	0.5-1	0.5-1		1.1	Gray-scale discrimination and contrast is poor to fair. U mapping nearly same as band 8 and 9. Distinct semicircula over entire image; anomalous darkening in SW corner.
	11 1.48-1.85 μm	11	A=0.5 B=0.5-1 C= 0.6	ca. 30	0-1	0-1	0-0.5	1-2	0		0.6	Poor gray-scale discrimination. Some topographic detail vi dissected areas. Open water very clearly defined. Quality than band 12 but nearly useless for GG mapping. Strong se scanner noise (probably related to smaller signal-noise ra longer wavelength.)
	12 2.00-2.43 μm	13	A=0-0.5 B=0.5 C= 0.4	ca. 35	0-0.5	0-0.5	0-0.5	1	0		0.4	Very poor contrast and sharpness of detail. A few topogra are seen in the highly dissected areas. Open water not as defined as in band 11. Very strong scanner noise, similar and 13-1. Useless for GG mapping.
MIDDLE IR (emissive)	13-1 10.20-12.50 μm	21	A=0 B=0-0.5 C= 0.1	ca. 35	0	0	0	1-2	0		0.3	Very strong semicircular scanner noise; NW half of image than SE half. Very poor gray-scale discrimination. Highly bluffs along the Illinois, Mississippi and Missouri Rivers visible. Larger open-water bodies are as distinct as in b Useless for GG mapping.

FOOTNOTES

[1]The S 192 photo images contain short tick marks every 100 scan-lines and longer tick marks every 1000 scan-lines. Only one 1000 scan-line tick appears in each scene, near the center of the border of the scene.

[2]Numerical rating system for image quality and utility for geomorphic-geographic mapping:
0 = none (nil); 1 = poor;
2 = fair; 3 = good; 4 = excellent.

Summary for this flight (all bands): Poor processing has resulted in images deficient in subtle gray differences. At more than 4X magnification, pixels begin to fuzz and show serrated edges and those that co with adjacent ones show severe blooming. For this reason, spatial resolution is somewhat poorer than the be images; however, on the sharper S192 images, small towns are visible and roads as narrow as 25 m. The 80% obscures information on soils and surficial materials. In the bands with better gray-scale discrimination, topographic features show by shadowing, even though the sun-elevation angle is relatively high. Thin cloud Mississippi River near NW edge of the scene blurs ground features in the shorter wavelength bands, especial the IR bands penetrate haze and thin clouds well, and also afford sharp discrimination of the larger ice-fre such as those along the Illinois, Mississippi, and Missouri Rivers. Random semicircular scanner-interruptio present in all bands. Scanner noise is evident over part or all of bands 9-13 and is so strong in bands 11- all details of topography except a few details in the highly dissected areas. Images from this scene are so quality than those from NE Kansas-NW Missouri (Sheet 1 of this series). The images from bands 3, 4, 5, 7, 8 approximately equal in quality; band 3 is the best. The above bands have poor to fair GG mapping utility; b have limited use, and bands 12 and 13-1 are useless.

ABBREVIATIONS

GG = geomorphic-geographic
GMT = Greenwich mean time
IR = infrared
MSS = multispectral scanner
SDO = scientific data output
μm = micrometer

Comparison with Skylab photographs: Both S190A and S190B photos are available for this flight. I moderate to severe over-exposure for snow covered areas, they show topographic and cultural features in muc (particularly the S190B photos) than any of the S192 bands.

Comparison with Landsat-1 MSS images: Landsat-1 snow-covered scenes from eastern Iowa-northwestern Illinoi frame 1144-16163, Dec. 14, 1972) and north-central Missouri (bands 5 and 6, frame 1200-16282, Feb. 8, 1973) comparison with the S192 images. The Landsat-1 images are superior in gray-scale discrimination and show topographic detail in the snow-covered areas. Small towns are more difficult to distinguish because of poo minimum road widths observed are equivalent to the better S192 bands, ie., about 25 m.

[3] See Table 5 for revised spectral ranges.

	SDO no.	IMAGE QUALITY[2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	Land-surface form factors (slope, local relief, pro...	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
μm a)	18	A= 0.5-1 B= 0.5-1.5 C= 0.9	ca. 30	0-1	0-1	0-1	0-1	0.5-1		0.6	Poor cloud-snow discrimination. Thin clouds near center of northern edge blur ground detail. Much loss of contrast and sharpness of detail because of scattering. Over-exposed and washed-out in snow-covered areas. Nearly useless for GG mapping.
μm	1	A= 1.5 B= 1.5-2 C= 1.6	ca. 25	1-2	1-2	0.5-1.5	0-1	1		1.1	Fair gray-scale discrimination and utility for GG mapping. Some random semicircular scanner-interruption lines.
μm en)	3	A= 1.5 B= 1-2 C=1.5	ca. 25	1-2	1-2	0.5-1.5	0.5	1		1.1	Field patterns and other features on the Illinois and Mississippi River alluvial lowlands are fairly well defined. Quality and utility of this band are comparable with bands 7, 8, and 9. Several semicircular scanner-interruption lines.
μm	5	A=1.5 B=0.5-2 C= 1.4	ca. 25	0.5-2	0-2	0.5-1.5	0.5	1		1.0	Somewhat overexposed. Gray-scale discrimination is fair in snow-free areas but very poor in snowy areas. Semicircular scanner-interruption lines present.
μm	7	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 35	0-1	0-1	0-1	0.5	0.5-1		0.6	Severely overexposed and too contrasty. Gray-scale discrimination poor (washed-out) in snow-covered areas.
μm	9	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5-1	0.5-1		1.1	Poor to fair contrast, gray-scale discrimination, and utility for GG mapping. Open-water discrimination better than in visible bands. Several prominent semicircular scanner-interruption lines.
μm	19	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	0.5-1.5	0.5-1	1		1.2	Poor to fair gray-scale discrimination. Open water of the major rivers stands out better than in the visible spectral range.
μm	20	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1-2	1	0.5-1	1		1.2	Gray-scale discrimination poor to fair. Good penetration of haze and clouds improves discrimination of terrain detail in the clouded areas. One very prominent semicircular scanner-interruption line. Anomalous darkening in SW corner probably related to semicircular scanner noise.
μm	17	A=1-1.5 B=1-2 C= 1.4	ca. 30	1-2	1-2	1	0.5-1	0.5-1		1.1	Gray-scale discrimination and contrast is poor to fair. Utility for GG mapping nearly same as band 8 and 9. Distinct semicircular scanner noise over entire image; anomalous darkening in SW corner.
μm	11	A=0.5 B=0.5-1 C= 0.6	ca. 30	0-1	0-1	0-0.5	1-2	0		0.6	Poor gray-scale discrimination. Some topographic detail visible in highly dissected areas. Open water very clearly defined. Quality somewhat better than band 12 but nearly useless for GG mapping. Strong semicircular scanner noise (probably related to smaller signal-noise ratio at this longer wavelength.)
μm	13	A=0-0.5 B=0.5 C= 0.4	ca. 35	0-0.5	0-0.5	0-0.5	1	0		0.4	Very poor contrast and sharpness of detail. A few topographic features are seen in the highly dissected areas. Open water not as clearly defined as in band 11. Very strong scanner noise, similar to bands 11 and 13-1. Useless for GG mapping.
μm	21	A=0 B=0-0.5 C= 0.1	ca. 35	0	0	0	1-2	0		0.3	Very strong semicircular scanner noise; NW half of image is much darker than SE half. Very poor gray-scale discrimination. Highly dissected bluffs along the Illinois, Mississippi and Missouri Rivers are faintly visible. Larger open-water bodies are as distinct as in band 11. Useless for GG mapping.

TNOTES

...o images contain ...ks every 100 scan-...er tick marks every ...s. Only one 1000 ... appears in each ...e center of the ...scene.

...ng system for image ...ility for ...graphic mapping: ... 1 = poor; ...good; 4 = excellent.

Summary for this flight (all bands): Poor processing has resulted in images deficient in subtle gray-scale differences. At more than 4X magnification, pixels begin to fuzz and show serrated edges and those that contrast highly with adjacent ones show severe blooming. For this reason, spatial resolution is somewhat poorer than the better Landsat-1 images; however, on the sharper S192 images, small towns are visible and roads as narrow as 25 m. The 80% snow cover obscures information on soils and surficial materials. In the bands with better gray-scale discrimination, some subtle topographic features show by shadowing, even though the sun-elevation angle is relatively high. Thin cloud cover near the Mississippi River near NW edge of the scene blurs ground features in the shorter wavelength bands, especially band 2. All the IR bands penetrate haze and thin clouds well, and also afford sharp discrimination of the larger ice-free water bodies, such as those along the Illinois, Mississippi, and Missouri Rivers. Random semicircular scanner-interruption lines are present in all bands. Scanner noise is evident over part or all of bands 9-13 and is so strong in bands 11-13 as to obscure all details of topography except a few details in the highly dissected areas. Images from this scene are somewhat better quality than those from NE Kansas-NW Missouri (Sheet 1 of this series). The images from bands 3, 4, 5, 7, 8, 9, and 10 are approximately equal in quality; band 3 is the best. The above bands have poor to fair GG mapping utility; bands 2, 6, 11 have limited use, and bands 12 and 13-1 are useless.

...VIATIONS

...hic-geographic ...gh mean time ...d ...ectral scanner ...fic data output ...ter

Comparison with Skylab photographs: Both S190A and S190B photos are available for this flight. In spite of moderate to severe over-exposure for snow covered areas, they show topographic and cultural features in much greater detail (particularly the S190B photos) than any of the S192 bands.

Comparison with Landsat-1 MSS images: Landsat-1 snow-covered scenes from eastern Iowa-northwestern Illinois (bands 5 and 6, Frame 1144-16163, Dec. 14, 1972) and north-central Missouri (bands 5 and 6, frame 1200-16282, Feb. 8, 1973) were used for comparison with the S192 images. The Landsat-1 images are superior in gray-scale discrimination and show much more topographic detail in the snow-covered areas. Small towns are more difficult to distinguish because of poor contrast; minimum road widths observed are equivalent to the better S192 bands, ie., about 25 m.

3 See Table 5 for revised spectral ranges.

...RIGINAL PAGE IS ...F POOR QUALITY

FOLDOUT FRAME 4

FOLDOUT FRAME /

TABLE 3. EVALUATION CHART FOR SKYLAB S 192 MULTISPECTRAL SCANNER IMAGES (page

MISSION: SL4
SYSTEM: S192 (MSS)
TRACK: 1
FLIGHT DATE: 1/12/74
PASS/ORBIT NO.: 82
GMT START: 16: 53' 2.4304"
GMT STOP (est'd): 16: 53' 18.9996"
SCALE OF SCENE: 1:800,000
CLOUD COVER (%): 0
SNOW COVER (%): 90

DATA FOR THE 1000 SCAN TICK[1]

GMT: 16: 53' 12.9691"

CO-ORDINATES (in direction of flight)

LEFT: N Lat. 39°59'14.0"
W Long. 90°3'1"

CENTER: N Lat. 39°41'13.9"
W Long. 89°51'19.8"

RIGHT: N Lat. 39°23'13.9"
W Long. 89°40'15.6"

STATE COVERAGE AND KEY GEOGRAPHIC FEATURES:
This image is in west-central Illinois and is the NE conti
scene reviewed on page 2 of this series.
The SW to NE flight path extends from 34.5 km SW of Jacks
29.5 km NE of Springfield, Ill. The Illinois River crosse
just north of Montezuma, Illinois for a distance of 14.5
the moderately dissected areas to the SW, the terrain is
plains, dissected only by the Sangamon River (which crosse
of the image) and its tributaries. Alluvial lowlands alon
river are approximately 5 km wide; local relief of the ad
is 70 m.

SPECTRAL REGION	BAND MSS spectral range[3]	SDO no.	IMAGE QUALITY[2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
VISIBLE (reflective)	2 0.44-0.52 µm (blue-green)	18	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 25	0-1	0-1	0-0.5	0-1	0.5-1		0.5	Overexposed and washed-out in snow-covered areas, much te invisible. A few semicircular scanner-interruption lines utility poor.
	3 0.49-0.56 µm (green)	1	A=1.5 B=1.5-2 C= 1.6	ca. 20	1.5-2	1.5-2	1-1.5	0-1	1		1.3	Gray-scale discrimination poor to fair, some subtle topog show by shadowing in the snow-covered areas. Random semic interruption lines. Best band in series for GG mapping.
	4 0.53-0.61 µm (yellow-green)	3	A=1.5 B=1-2 C= 1.5	ca. 20	1-2	1.5-2	0.5-1.5	0-1	1		1.2	Gray-scale discrimination poor to fair, nearly as good as Semicircular scanner noise over entire image and several interruption lines. Quality and utility of band for GG ma Fa.
	5 0.59-0.67 µm (orange)	5	A=1-1.5 B=1-1.5 C=1.3	ca. 20	1-2	1-2	0.5-1.5	0-1	1		1.1	Somewhat overexposed. Contrast and gray-scale discriminat Pixel boundaries are very fuzzy; high-contrast ones commo blooming. Semicircular scanner noise over entire frame; Interruption lines. Quality and utility for mapping near for bands 3 and 4.
	6 0.64-0.75 µm (red)	7	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 40	0-1	0-1	0-0.5	0-1	0.5-1		0.5	Severely over-exposed and too contrasty. Gray-scale disc (washed-out) in snow-covered areas, where terrain details invisible. Poor utility for GG mapping.
NEAR IR (reflective)	7 0.75-0.90 µm	9	A=1-1.5 B=1-2 C= 1.4	ca. 25	1-1.5	1-2	0.5-1.5	0.5-1	1		1.1	Contrast and gray-scale discrimination poor to fair. Sem noise more evident than in previous bands; several scanne lines. Comparable in quality and utility with bands 8 an
	8 0.90-1.08 µm	19	A=1.5 B=1-2 C=1.5	ca. 25	1-2	1.5-2	0.5-1.5	0.5-1	1		1.2	Gray-scale discrimination poor to fair. Shadowing in sno reveals some subtle topographic details. Several scanne lines. Semicircular scanner noise over entire image, wit darkening at center of NE edge.
	9 1.00-1.24 µm	20	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1.5-2	0.5-1.5	0.5-1	1		1.2	Poor to fair gray-scale discrimination, pixels begin to than 4X magnification. Several scanner-interruption line scanner noise covers entire image but generally does not degrade detail. Darkening of image at center of NE edge Ill., stronger than in band 8.
	10 1.10-1.35 µm	17	A=1-1.5 B=0.5-2 C=1.3	ca. 30	1-1.5	1-2	0.5-1.5	0.5-1	0.5-1		1.1	Strong scanner noise over entire image, especially darken thru center third of frame (lengthwise). Open-water of Il more distinct than in previous bands but not as distinct Gray-scale discrimination and contrast are fairly poor. GG mapping than band 9.
	11 1.48-1.85 µm	11	A=0.5 B=0-1 C=0.5	ca. 35	0-0.5	0-0.5	0-0.5	1-1.5	0		0.4	Somewhat over-all better quality than band 12. Very stro scanner noise; random scanner-interruption lines. Topog visible only in highly dissected areas. Open-water along is very distinct. Useless for GG mapping.
	12 2.00-2.43 µm	13	A=0-0.5 B=0-0.5 C=0.3	>35	0-0.5	0-0.5	0-0.5	0-0.5	0		0.2	Darker and stronger scanner noise than band 11; several interruption lines. Very poor contrast and sharpness of detail is faintly visible in highly dissected areas. Op Illinois River is somewhat less distinct than in band 11 GG mapping.
MIDDLE IR (emissive)	13-1 10.20-12.50 µm	21	A=0 B=0-0.5 C=0.1	>35	0	0	0	0.5-1.5	0		0.2	Best band for open-water discrimination; but only the la be seen, e.g., Illinois River, Lake Kincaid SE of Spring of Sangamon River and Salt Creek. Topographic detail is visible in the more highly dissected areas. Useless for

FOOTNOTES

[1]The S 192 photo images contain short tick marks every 100 scan-lines and longer tick marks every 1000 scan-lines. Only one 1000 scan-line tick appears in each scene, near the center of the

Summary for this flight (all bands): These images are generally similar in quality to those reviewe this Table, and somewhat better than those listed on sheet I. Cloud-free, but 90% snow cover obscures soils and surficial materials. Bands 3,4,5,7,8,9, and 10 are approximately equal in quality (band 3 is th poor to fair utility for GG mapping. Bands 2 and 6 are badly over-exposed (washed-out) for the snow-covere very limited utility for GG mapping. Bands 11, 12, and 13-1 are useless because of very poor sharpness and discrimination resulting from high noise-to-signal ratio. The IR bands show open-water bodies more clearl region bands--albeit only the larger water bodies

Even the best-quality band (3) has poorer ground resolution than the better Landsat-1 images. In all pixels begin to fuzz under magnification greater than 4X; they also show serrated edges and those that co

FOLDOUT FRAME 2

:VALUATION CHART FOR SKYLAB S 192 MULTISPECTRAL SCANNER IMAGES (page 3 of 3)

ISS)

2/74

82

3' 2.4304"

); 16: 53' 18.9996"

1:800,000

: 0

90

DATA FOR THE 1000 SCAN TICK [1]

GMT: 16: 53' 12.9691"

CO-ORDINATES (in direction of flight)

LEFT: N Lat. 39°59'14.0"
W Long. 90°3'1"

CENTER: N Lat. 39°41'13.9"
W Long. 89°51'19.8"

RIGHT: N Lat. 39°23'13.9"
W Long. 89°40'15.6"

STATE COVERAGE AND KEY GEOGRAPHIC FEATURES:

This image is in west-central Illinois and is the NE continuation of the scene reviewed on page 2 of this series.
The SW to NE flight path extends from 34.5 km SW of Jacksonville, Ill. to 29.5 km NE of Springfield, Ill. The Illinois River crosses the NW corner just north of Montezuma, Illinois for a distance of 14.5 km. Except for the moderately dissected areas to the SW, the terrain is gently rolling plains, dissected only by the Sangamon River (which crosses the east half of the image) and its tributaries. Alluvial lowlands along the Illinois river are approximately 5 km wide; local relief of the adjacent bluffs is 70 m.

	SDO no.	IMAGE QUALITY [2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	UTILITY FOR MAPPING KEY GEOMORPHIC/GEOGRAPHIC CHARACTERISTICS: Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
µm n)	18	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 25	0-1	0-1	0-0.5	0-1	0.5-1		0.5	Overexposed and washed-out in snow-covered areas, much terrain detail invisible. A few semicircular scanner-interruption lines. GG mapping utility poor.
µm	1	A=1.5 B=1.5-2 C= 1.6	ca. 20	1.5-2	1.5-2	1-1.5	0-1	1		1.3	Gray-scale discrimination poor to fair, some subtle topographic features show by shadowing in the snow-covered areas. Random semicircular scanner-interruption lines. Best band in series for GG mapping.
µm een)	3	A=1.5 B=1-2 C= 1.5	ca. 20	1-2	1.5-2	0.5-1.5	0-1	1		1.2	Gray-scale discrimination poor to fair, nearly as good as band 3. Semicircular scanner noise over entire image and several scanner-interruption lines. Quality and utility of band for GG mapping poor to fair.
µm)	5	A=1-1.5 B=1-1.5 C= 1.3	ca. 20	1-2	1-2	0.5-1.5	0-1	1		1.1	Somewhat overexposed. Contrast and gray-scale discrimination poor to fair. Pixel boundaries are very fuzzy; high-contrast ones commonly show blooming. Semicircular scanner noise over entire frame; random scanner-interruption lines. Quality and utility for mapping nearly as good as for bands 3 and 4.
µm	7	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 40	0-1	0-1	0-0.5	0-1	0.5-1		0.5	Severely over-exposed and too contrasty. Gray-scale discrimination poor (washed-out) in snow-covered areas, where terrain details commonly are invisible. Poor utility for GG mapping.
µm	9	A=1-1.5 B=1-2 C= 1.4	ca. 25	1-1.5	1-2	0.5-1.5	0.5-1	1		1.1	Contrast and gray-scale discrimination poor to fair. Semicircular scanner noise more evident than in previous bands; several scanner-interruption lines. Comparable in quality and utility with bands 8 and 9.
µm	19	A=1.5 B=1-2 C=1.5	ca. 25	1-2	1.5-2	0.5-1.5	0.5-1	1		1.2	Gray-scale discrimination poor to fair. Shadowing in snow-covered uplands reveals some subtle topographic details. Several scanner-interruption lines. Semicircular scanner noise over entire image, with anomalous darkening at center of NE edge.
µm	20	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1.5-2	0.5-1.5	0.5-1	1		1.2	Poor to fair gray-scale discrimination, pixels begin to fuzz with greater than 4X magnification. Several scanner-interruption lines, semicircular scanner noise covers entire image but generally does not seriously degrade detail. Darkening of image at center of NE edge to Springfield, Ill., stronger than in band 8.
µm	17	A=1-1.5 B=0.5-2 C=1.3	ca. 30	1-1.5	1-2	0.5-1.5	0.5-1	0.5-1		1.1	Strong scanner noise over entire image, especially darkened NE edge and thru center third of frame (lengthwise). Open-water of Illinois River is more distinct than in previous bands but not as distinct as in band 11. Gray-scale discrimination and contrast are fairly poor. Less useful for GG mapping than band 9.
µm	11	A=0.5 B=0-1 C=0.5	ca. 35	0-0.5	0-0.5	0-0.5	1-1.5	0		0.4	Somewhat over-all better quality than band 12. Very strong semicircular scanner noise; random scanner-interruption lines. Topographic detail visible only in highly dissected areas. Open-water along Illinois River is very distinct. Useless for GG mapping.
µm	13	A=0-0.5 B=0-0.5 C=0.3	>35	0-0.5	0-0.5	0-0.5	0-0.5	0		0.2	Darker and stronger scanner noise than band 11; several scanner-interruption lines. Very poor contrast and sharpness of detail; topographic detail is faintly visible in highly dissected areas. Open water along Illinois River is somewhat less distinct than in band 11. Useless for GG mapping.
µm	21	A=0 B=0-0.5 C=0.1	>35	0	0	0	0.5-1.5	0		0.2	Best band for open-water discrimination; but only the larger bodies can be seen, e.g., Illinois River, Lake Kincaid SE of Springfield, and parts of Sangamon River and Salt Creek. Topographic detail is very faintly visible in the more highly dissected areas. Useless for GG mapping.

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ks every 100 scan-
er tick marks every
s. Only one 1000
appears in each

Summary for this flight (all bands): These images are generally similar in quality to those reviewed on sheet 2 of this Table, and somewhat better than those listed on sheet 1. Cloud-free, but 90% snow cover obscures information on soils and surficial materials. Bands 3,4,5,7,8,9, and 10 are approximately equal in quality (band 3 is the best) and have poor to fair utility for GG mapping. Bands 2 and 6 are badly over-exposed (washed-out) for the snow-covered areas and have very limited utility for GG mapping. Bands 11, 12, and 13-1 are useless because of very poor sharpness and gray-scale discrimination resulting from high noise-to-signal ratio. The IR bands show open-water bodies more clearly than the visible region bands--albeit only the larger water bodies

Even the best-quality band (3) has poorer ground resolution than the better Landsat-1 images. In all the bands, the

SPECTRAL REGION	BAND MSS spectral range[3]	SDO no.	IMAGE QUALITY[2] A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	Land-surface form factors (slope, local relief, p…	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
VISIBLE (reflective)	2 0.44-0.52 µm (blue-green)	18	A=0.5-1 B=0.5-1.5 C=0.9	ca. 25	0-1	0-1	0-0.5	0-1	0.5-1		0.5	Overexposed and washed-out in snow-covered areas, much ter… invisible. A few semicircular scanner-interruption lines. … utility poor.
	3 0.49-0.56 µm (green)	1	A=1.5 B=1.5-2 C= 1.6	ca. 20	1.5-2	1.5-2	1-1.5	0-1	1		1.3	Gray-scale discrimination poor to fair, some subtle topogr… show by shadowing in the snow-covered areas. Random semic… interruption lines. Best band in series for GG mapping.
	4 0.53-0.61 µm (yellow-green)	3	A=1.5 B=1-2 C= 1.5	ca. 20	1-2	1.5-2	0.5-1.5	0-1	1		1.2	Gray-scale discrimination poor to fair, nearly as good as … Semicircular scanner noise over entire image and several s… interruption lines. Quality and utility of band for GG ma… fair.
	5 0.59-0.67 µm (orange)	5	A=1-1.5 B=1-1.5 C=1.3	ca. 20	1-2	1-2	0.5-1.5	0-1	1		1.1	Somewhat overexposed. Contrast and gray-scale discriminat… Pixel boundaries are very fuzzy; high-contrast ones commo… blooming. Semicircular scanner noise over entire frame; … interruption lines. Quality and utility for mapping near… for bands 3 and 4.
	6 0.64-0.75 µm (red)	7	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 40	0-1	0-1	0-0.5	0-1	0.5-1		0.5	Severely over-exposed and too contrasty. Gray-scale disc… (washed-out) in snow-covered areas, where terrain details… invisible. Poor utility for GG mapping.
NEAR IR (reflective)	7 0.75-0.90 µm	9	A=1-1.5 B=1-2 C= 1.4	ca. 25	1-1.5	1-2	0.5-1.5	0.5-1	1		1.1	Contrast and gray-scale discrimination poor to fair. Sem… noise more evident than in previous bands; several scanne… lines. Comparable in quality and utility with bands 8 an…
	8 0.90-1.08 µm	19	A=1.5 B=1-2 C=1.5	ca. 25	1-2	1.5-2	0.5-1.5	0.5-1	1		1.2	Gray-scale discrimination poor to fair. Shadowing in sno… reveals some subtle topographic details. Several scanner-… lines. Semicircular scanner noise over entire image, wit… darkening at center of NE edge.
	9 1.00-1.24 µm	20	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1.5-2	0.5-1.5	0.5-1	1		1.2	Poor to fair gray-scale discrimination, pixels begin to f… than 4X magnification. Several scanner-interruption line… scanner noise covers entire image but generally does not … degrade detail. Darkening of image at center of NE edge … Ill., stronger than in band 8.
	10 1.10-1.35 µm	17	A=1-1.5 B=0.5-2 C=1.3	ca. 30	1-1.5	1-2	0.5-1.5	0.5-1	0.5-1		1.1	Strong scanner noise over entire image, especially darken… thru center third of frame (lengthwise). Open-water of Il… more distinct than in previous bands but not as distinct … Gray-scale discrimination and contrast are fairly poor. … GG mapping than band 9.
	11 1.48-1.85 µm	11	A=0.5 B=0-1 C=0.5	ca. 35	0-0.5	0-0.5	0-0.5	1-1.5	0		0.4	Somewhat over-all better quality than band 12. Very stron… scanner noise; random scanner-interruption lin… Topogr… visible only in highly dissected areas. Open-water along… is very distinct. Useless for GG mapping.
	12 2.00-2.43 µm	13	A=0-0.5 B=0-0.5 C=0.3	>35	0-0.5	0-0.5	0-0.5	0-0.5	0		0.2	Darker and stronger scanner noise than band 11; several s… interruption lines. Very poor contrast and sharpness of … detail is faintly visible in highly dissected areas. Ope… Illinois River is somewhat less distinct than in band 11. … GG mapping.
MIDDLE IR (emissive)	13-1 10.20-12.50 µm	21	A=0 B=0-0.5 C=0.1	>35	0	0	0	0.5-1.5	0		0.2	Best band for open-water discrimination; but only the lar… be seen, e.g., Illinois River, Lake Kincaid SE of Springf… of Sangamon River and Salt Creek. Topographic detail is v… visible in the more highly dissected areas. Useless for …

FOOTNOTES

[1]The S 192 photo images contain short tick marks every 100 scan-lines and longer tick marks every 1000 scan-lines. Only one 1000 scan-line tick appears in each scene, near the center of the border of the scene.

[2]Numerical rating system for image quality and utility for geomorphic-geographic mapping: 0 = none (nil); 1 = poor; 2 = fair; 3 = good; 4 = excellent.

ABBREVIATIONS

GG = geomorphic-geographic
GMT = Greenwich mean time
IR = infrared
MSS = multispectral scanner
SDO = scientific data output
µm = micrometer

Summary for this flight (all bands): These images are generally similar in quality to those reviewe… this Table, and somewhat better than those listed on sheet 1. Cloud-free, but 90% snow cover obscures … soils and surficial materials. Bands 3,4,5,7,8,9, and 10 are approximately equal in quality (band 3 is the… poor to fair utility for GG mapping. Bands 2 and 6 are badly over-exposed (washed-out) for the snow-covered… very limited utility for GG mapping. Bands 11, 12, and 13-1 are useless because of very poor sharpness and … discrimination resulting from high noise-to-signal ratio. The IR bands show open-water bodies more clearly… region bands--albeit only the larger water bodies

Even the best-quality band (3) has poorer ground resolution than the better Landsat-1 images. In all … pixels begin to fuzz under magnification greater than 4X; they also show serrated edges and those that cont… with adjacent ones show severe blooming. Random scanner-interruption lines are present in all bands, and s… scanner noise is present in all bands except 2,3, and 6. In bands 9 and 10 the scanner noise is strong, an… it is so strong that it obscures all topographic features except the larger ones in the most highly dissect… Anomalous darkening of the NE edge of band 9 and of the central third (lengthwise) of band 10 results in de… sharpness of detail.

Comparison with Skylab photographs: This scene is a northeastward continuation of the scene evaluat… preceding page; comparisons with Skylab photographs and Landsat-1 MSS images generally similar.

Comparison with Landsat-1 MSS images: (See above).

[3] See Table 5 for revised spectral ranges.

	SDO no.	IMAGE QUALITY A=sharpness of detail B=contrast and gray-scale discrimination C=average (mean) quality	DETECTIBILITY (minimum dimension in meters) ROADS	Land-surface form factors (slope, local relief, profile)	Stream order and pattern	Valley lowlands	Water surfaces: lakes, ponds, flowing streams	Urbanized areas		Average (mean) utility	GENERAL REMARKS individual bands: quality and utility
m .)	18	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 25	0-1	0-1	0-0.5	0-1	0.5-1		0.5	Overexposed and washed-out in snow-covered areas, much terrain detail invisible. A few semicircular scanner-interruption lines. GG mapping utility poor.
.m	1	A=1.5 B=1.5-2 C= 1.6	ca. 20	1.5-2	1.5-2	1-1.5	0-1	1		1.3	Gray-scale discrimination poor to fair, some subtle topographic features show by shadowing in the snow-covered areas. Random semicircular scanner-interruption lines. Best band in series for GG mapping.
um :n)	3	A=1.5 B=1-2 C= 1.5	ca. 20	1-2	1.5-2	0.5-1.5	0-1	1		1.2	Gray-scale discrimination poor to fair, nearly as good as band 3. Semicircular scanner noise over entire image and several scanner-interruption lines. Quality and utility of band for GG mapping poor to fair.
um	5	A=1-1.5 B=1-1.5 C= 1.3	ca. 20	1-2	1-2	0.5-1.5	0-1	1		1.1	Somewhat overexposed. Contrast and gray-scale discrimination poor to fair. Pixel boundaries are very fuzzy; high-contrast ones commonly show blooming. Semicircular scanner noise over entire frame; random scanner-interruption lines. Quality and utility for mapping nearly as good as for bands 3 and 4.
um	7	A=0.5-1 B=0.5-1.5 C= 0.9	ca. 40	0-1	0-1	0-0.5	0-1	0.5-1		0.5	Severely over-exposed and too contrasty. Gray-scale discrimination poor (washed-out) in snow-covered areas, where terrain details commonly are invisible. Poor utility for GG mapping.
um	9	A=1-1.5 B=1-2 C= 1.4	ca. 25	1-1.5	1-2	0.5-1.5	0.5-1	1		1.1	Contrast and gray-scale discrimination poor to fair. Semicircular scanner noise more evident than in previous bands; several scanner-interruption lines. Comparable in quality and utility with bands 8 and 9.
µm	19	A=1.5 B=1-2 C=1.5	ca. 25	1-2	1.5-2	0.5-1.5	0.5-1	1		1.2	Gray-scale discrimination poor to fair. Shadowing in snow-covered uplands reveals some subtle topographic details. Several scanner-interruption lines. Semicircular scanner noise over entire image, with anomalous darkening at center of NE edge.
µm	20	A=1.5 B=1-2 C= 1.5	ca. 25	1-2	1.5-2	0.5-1.5	0.5-1	1		1.2	Poor to fair gray-scale discrimination, pixels begin to fuzz with greater than 4X magnification. Several scanner-interruption lines, semicircular scanner noise covers entire image but generally does not seriously degrade detail. Darkening of image at center of NE edge to Springfield, Ill., stronger than in band 8.
µm	17	A=1-1.5 B=0.5-2 C=1.3	ca. 30	1-1.5	1-2	0.5-1.5	0.5-1	0.5-1		1.1	Strong scanner noise over entire image, especially darkened NE edge and thru center third of frame (lengthwise). Open-water of Illinois River is more distinct than in previous bands but not as distinct as in band 11. Gray-scale discrimination and contrast are fairly poor. Less useful for GG mapping than band 9.
µm	11	A=0.5 B=0-1 C=0.5	ca. 35	0-0.5	0-0.5	0-0.5	1-1.5	0		0.4	Somewhat over-all better quality than band 12. Very strong semicircular scanner noise; random scanner-interruption lines. Topographic detail visible only in highly dissected areas. Open-water along Illinois River is very distinct. Useless for GG mapping.
µm	13	A=0-0.5 B=0-0.5 C=0.3	>35	0-0.5	0-0.5	0-0.5	0-0.5	0		0.2	Darker and stronger scanner noise than band 11; several scanner-interruption lines. Very poor contrast and sharpness of detail; topographic detail is faintly visible in highly dissected areas. Open water along Illinois River is somewhat less distinct than in band 11. Useless for GG mapping.
µm	21	A=0 B=0-0.5 C=0.1	>35	0	0	0	0.5-1.5	0		0.2	Best band for open-water discrimination; but only the larger bodies can be seen, e.g., Illinois River, Lake Kincaid SE of Springfield, and parts of Sangamon River and Salt Creek. Topographic detail is very faintly visible in the more highly dissected areas. Useless for GG mapping.

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<u>Summary for this flight (all bands):</u> These images are generally similar in quality to those reviewed on sheet 2 of this Table, and somewhat better than those listed on sheet 1. Cloud-free, but 90% snow cover obscures information on soils and surficial materials. Bands 3,4,5,7,8,9, and 10 are approximately equal in quality (band 3 is the best) and have poor to fair utility for GG mapping. Bands 2 and 6 are badly over-exposed (washed-out) for the snow-covered areas and have very limited utility for GG mapping. Bands 11, 12, and 13-1 are useless because of very poor sharpness and gray-scale discrimination resulting from high noise-to-signal ratio. The IR bands show open-water bodies more clearly than the visible region bands--albeit only the larger water bodies

Even the best-quality band (3) has poorer ground resolution than the better Landsat-1 images. In all the bands, the pixels begin to fuzz under magnification greater than 4X; they also show serrated edges and those that contrast strongly with adjacent ones show severe blooming. Random scanner-interruption lines are present in all bands, and semicircular scanner noise is present in all bands except 2,3, and 6. In bands 9 and 10 the scanner noise is strong, and in bands 11-13 it is so strong that it obscures all topographic features except the larger ones in the most highly dissected areas. Anomalous darkening of the NE edge of band 9 and of the central third (lengthwise) of band 10 results in degradation of sharpness of detail.

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<u>Comparison with Skylab photographs:</u> This scene is a northeastward continuation of the scene evaluated on the preceding page; comparisons with Skylab photographs and Landsat-1 MSS images generally similar.

<u>Comparison with Landsat-1 MSS images:</u> (See above).

3 See Table 5 for revised spectral ranges.

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resolution is too poor, however, to show the smaller water bodies. In addition, these bands have good capability to penetrate haze and thin clouds; bands 10, 11, and 12 provide good discrimination between the thicker clouds and snow-covered terrain.

In conclusion, bands 3, 4, 5, 7, 8, 9, and 10 are nearly equal in ground resolution and image quality, and have poor to fair utility for geomorphic-geographic mapping. Bands 2, 6, 11, 12, and 13-1 are extremely poor to poor in ground resolution and image quality and nearly to entirely useless for geomorphic-geographic mapping.

The better Landsat-1 MSS images are superior to the better S192 MSS images in spatial resolution and gray-scale discrimination--and the Skylab S190A MS photos of these same scenes are much superior in both respects, despite overexposure for the snow-covered areas. For example, roads as narrow as 10 m are detectable on the S190A photos, as narrow as 10-15 m on the Landsat-1 images, vs. 20 m on the best S192 images.

6.0 GENERAL COMPARISON OF SKYLAB S190A AND S190B PHOTOS AND S192 MULTISPECTRAL IMAGES WITH LANDSAT-1 MULTISPECTRAL IMAGES

Table 4 gives our evaluation of the relative overall quality and utility (for geomorphic-geographic mapping) of the S190A and S190B photos compared with S192 and ERTS (Landsat)-1 multispectral images of this region.

Table 4.--NEAR HERE

Strong advantages of the Landsat-1 images are: the somewhat overlapping[3/] orbital paths and repetition of images of the same scenes every 18 days enabled complete, cloud-free, and multiseasonal coverage to be obtained of the entire project region. The repetitive images are valuable for detecting time-variant phenomena such as flooding, erosion, sedimentation, and changes in soil moisture, vegetation, and agricultural practice, as well as man-made ground disturbance and construction activities. The images not only have high planimetric accuracy but also each image provides a synoptic overview of a large region at the same sun-elevation angle. These attributes, together with the moderate ground resolution, provide a capability for distinguishing the larger landforms, landform assemblages, and geologic linears with greater clarity than with Skylab and ultrahigh aerial photographs (where these features become more difficult to pick out of the wealth of detail). In addition, much more information is recorded on the digital tapes than can be reproduced on photographic film (under the standard processing format), and the digital data can be manipulated and enhanced by computer in various ways. Disadvantages of the Landsat-1 images are moderate spatial resolution, relatively broad spectral resolution, and limited capability for stereoscopic viewing, due to the slight overlap between adjacent flight paths and to the limited parallax from the high orbital altitude.

[3/] Side overlap ranges from about 15 to 25% at the latitudes of the project region.

The chief advantages of the Skylab multispectral photos are their superior spatial (but not spectral) resolution, and, for many SL flights, full stereovision capability--a great advantage for geomorphologic and geologic investigations. Also, they have high planimetric accuracy due to the high orbital altitude and the high quality of the camera lenses. The S190B photos, of course, have even better spatial resolution than the S190A photos.

Adverse features of the SL photography of the Great Plains-Midwest are: (1) spotty coverage by high-quality photos free of clouds and severe haze; (2) very limited repetitive, multiseasonal coverage--the EREP flights were too infrequent to catch, for most areas, the best atmospheric conditions, the least vegetative cover, and the optimum differences (spread) in soil-moisture conditions; for many areas, the best-quality photos were taken in summer or winter, when either heavy vegetation or snow concealed information on soils and surficial materials; (3) although stereoscopic coverage was obtained on many flights, the relatively high orbital altitude results in a low base-height ratio and limits the capability for detecting slight relief differences by stereovision.

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TABLE 4. COMPARISON OF SKYLAB PHOTOGRAPHS/MULTISPECTRAL IMAGES and LANDSAT-I MULTISPECTRAL

IMAGING SYSTEM	SPECTRAL BAND[4]	ATTRIBUTE[3]: Sharpness of definition ("ground resolution")	Color quality (color & CIR photos)	Gray-scale or color-scale discrimination	Signal-to-noise ratio (MSS images)	Haze penetration	Shadow rendition		Repetitive, multiseasonal coverage	Regional coverage (comprehensiveness w/o gaps)	Stereoscopic coverage; stereovision	Metric (planimetric) capability	Water-body discrimination/detail	Cloud-snow discrimination	Water penetration	Vegetation discrimination	Agricultural ag land-use de	To
SKYLAB S190A MULTISPECTRAL PHOTOGRAPHS[1]	color (0.4-0.7 µm)	3-3.5	3-4	3-4	—	2	2-3		2	2.5	0-2.5	3	1-2.5	2	0.5	2-3	3-3.5	3-3.5
	color-infrared (0.5-0.88 µm)	2-3	3-4	2.5-3.5	—	3.5	2		2	2.5	0-2.5	3	2-3	1	0	3.5	2-3	2-3
	B/W infrared (0.7-0.8 µm)	0.5-1.5	—	1-2	—	3	1		2	2.5	0-2.5	2.5	1-3.5	1	0	0.5-2	1	0.5-1
	B/W infrared (0.8-0.9 µm)	0.5-1.5	—	0.5-2	—	3.5	1		2	2.5	0-2.5	2.5	1-3.5	1	0	0.5-2	0.5	0.5
	B/W red (0.6-0.7 µm)	3-3.5	—	2.5-3.5	—	2	2.5-3.5		2	2.5	0-2.5	3	1-3	1	0	2.5	3	3-3.5
	B/W green (0.5-0.6 µm)	2.5-3	—	1-2.5	—	1	1		2	2.5	0-2.5	3	1	0.5	2	1	1.5-3	1-2.5
SKYLAB S190B EARTH TERRAIN CAMERA[1]	color (0.4-0.7 µm)	3.5-4	3.5-4	3.5-4	—	2	2-3		2	2	0-3	3.5	1-3	2	1	2-3	3.5-4	3.5-4
SKYLAB S192 MULTISPECTRAL SCANNER (MSS) PHOTO IMAGES[2]	2 (0.44-0.52 µm; blue-green)	0-1	—	0.5-1.5	3	0.5	0		0.5	0.5	0	2	0-1	0	—	—	0.5	0-1
	3 (0.49-0.56 µm; green)	1-1.5	—	1-2	3	1	0.5-1		0.5	0.5	0	2	0-1	0.5	—	—	0.5	1-2
	4 (0.53-0.61 µm; yellow-green)	1-1.5	—	1-2	3	1.5	0.5		0.5	0.5	0	2	0-1	0.5	—	—	0.5	1-2
	5 (0.59-0.67 µm; yellow-red)	1-1.5	—	0.5-2	3	2	0.5		0.5	0.5	0	2	0-1	0.5	—	—	0.5	0.5-2
	6 (0.64-0.75 µm; red)	0-1	—	0.5-1.5	3	2	0		0.5	0.5	0	2	0-1	0	—	—	0-0.5	0-1
	7 (0.75-0.90 µm; near IR)	1-1.5	—	1-2	2.5	3	0.5-1		0.5	0.5	0	2	0-1.5	2	—	—	0.5-1	1-2
	8 (0.90-1.08 µm; near IR)	1-1.5	—	1-2	2	3	0.5-1		0.5	0.5	0	2	0-1.5	2	—	—	0.5	1-2
	9 (1.00-1.24 µm; near IR)	1-1.5	—	1-2	2	3	0.5		0.5	0.5	0	2	0-1.5	2	—	—	0.5	1-2
	10 (1.10-1.35 µm; near IR)	1-1.5	—	0.5-2	1.5	3	0		0.5	0.5	0	2	0-1	2.5	—	—	0-0.5	1-2
	11 (1.48-1.85 µm; near IR)	0.5	—	0-1	1	3	0		0.5	0.5	0	2	1-2	3	—	—	0	0-1
	12 (2.00-2.43 µm; near IR)	0-0.5	—	0-0.5	0.5	3	0		0.5	0.5	0	2	0-1	3	—	—	0	0-0.5
	13-1 (10.20-12.50µm; middle IR)	0-0.5	—	0-0.5	0.5	3	0		0.5	0.5	0	2	1	0	—	—	0	0
LANDSAT-I (ERTS-1) MULTISPECTRAL SCANNER (MSS) PHOTO IMAGES[3]	4 (0.5-0.6 µm; green)	0.5-2	—	0.5-2	2-3	1	1		4	4	1.5	3.5	0.5	0.5	2	0.5	0.5	0.5
	5 (0.6-0.7 µm; red)	2-2.5	—	2-3.5	3.5	2	3		4	4	1.5	3.5	1-2	1	0	2.5	1-3	1-2.5
	6 (0.7-0.8 µm; near IR)	2	—	2-3	3.5	3	2.5		4	4	1.5	3.5	2-3.5	1	0	2	1-2.5	1-2
	7 (0.8-1.1 µm; near IR)	2	—	2-3.5	3.5	3.5	2.5		4	4	1.5	3.5	2-3.5	1	0	2	1-3	1-2.5

FOOTNOTES:

[1]Better-quality unenlarged 3d-generation transparencies of the project region.

[2]Based on 3 snow-covered scenes from SL 4 mission, Tracks 1 and 58 (see Table 3.)

[3]Better-quality photo images (70 mm and/or 1:1 million-scale formats) of the

[4]See text Table 5 for revised wavelength ranges for the various Skylab spectr

[5]Numerical rating system: 1=poor, 2=fair, 3=good, 4=excellent.

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COMPARISON OF SKYLAB PHOTOGRAPHS/MULTISPECTRAL IMAGES and LANDSAT-I MULTISPECTRAL IMAGES

	SPECTRAL BAND[4] / ATTRIBUTE[5]	Sharpness of definition ("ground resolution")	Color quality (color & CIR photos)	Gray-scale or color-scale discrimination	Signal-to-noise ratio (MSS images)	Haze penetration	Shadow rendition	Repetitive, multiseasonal coverage	Regional coverage (comprehensiveness w/o gaps)	Stereoscopic coverage; stereovision	Metric (planimetric) capability	Water-body discrimination/detail	Cloud-snow discrimination	Water penetration	Vegetation discrimination	Agricultural and urban land-use detail	Topographic (landform and stream pattern) detail	Geologic linear detectability	Average value
	color (0.4-0.7 μm)	3-3.5	3-4	3-4	—	2	2-3	2	2.5	0-2.5	3	1-2.5	2	0.5	2-3	3-3.5	3-3.5	2-3	2.6
	color-infrared (0.5-0.88 μm)	2-3	3-4	2.5-3.5	—	3.5	2	2	2.5	0-2.5	3	2-3	1	0	3.5	2-3	2-3	2-3	2.4
	B/W infrared (0.7-0.8 μm)	0.5-1.5	—	1-2	—	3	1	2	2.5	0-2.5	2.5	1-3.5	1	0	0.5-2	1	0.5-1	0.5-1.5	1.5
	B/W infrared (0.8-0.9 μm)	0.5-1.5	—	0.5-2	—	3.5	1	2	2.5	0-2.5	2.5	1-3.5	1	0	0.5-2	0.5	0.5	0.5-1	1.3
	B/W red (0.6-0.7 μm)	3-3.5	—	2.5-3.5	—	2	2.5-3.5	2	2.5	0-2.5	3	1-3	1	0	2.5	3	3-3.5	2.5	2.3
	B/W green (0.5-0.6 μm)	2.5-3	—	1-2.5	—	1	1	2	2.5	0-2.5	3	1	0.5	2	1	1.5-3	1-2.5	0.5-1	1.7
RA[1]	color (0.4-0.7 μm)	3.5-4	3.5-4	3.5-4	—	2	2-3	2	2	0-3	3.5	1-3	2	1	2-3	3.5-4	3.5-4	2.5-3.5	2.7
	2 (0.44-0.52 μm; blue-green)	0-1	—	0.5-1.5	3	0.5	0	0.5	0.5	0	2	0-1	0	—	—	0.5	0-1	0.5	0.7
	3 (0.49-0.56 μm; green)	1-1.5	—	1-2	3	1	0.5-1	0.5	0.5	0	2	0-1	0.5	—	—	0.5	1-2	0.5-2	1.1
	4 (0.53-0.61 μm; yellow-green)	1-1.5	—	1-2	3	1.5	0.5	0.5	0.5	0	2	0-1	0.5	—	—	0.5	1-2	0.5-2	1.1
	5 (0.59-0.67 μm; yellow-red)	1-1.5	—	0.5-2	3	2	0.5	0.5	0.5	0	2	0-1	0.5	—	—	0.5	0.5-2	0.5-2	1.1
	6 (0.64-0.75 μm; red)	0-1	—	0.5-1.5	3	2	0	0.5	0.5	0	2	0-1	0	—	—	0-0.5	0-1	1	0.8
	7 (0.75-0.90 μm; near IR)	1-1.5	—	1-2	2.5	3	0.5-1	0.5	0.5	0	2	0-1.5	2	—	—	0.5-1	1-2	2.5	1.4
	8 (0.90-1.08 μm; near IR)	1-1.5	—	1-2	2	3	0.5-1	0.5	0.5	0	2	0-1.5	2	—	—	0.5	1-2	1-2	1.3
	9 (1.00-1.24 μm; near IR)	1-1.5	—	1-2	2	3	0.5	0.5	0.5	0	2	0-1.5	2	—	—	0.5	1-2	1-2	1.2
	10 (1.10-1.35 μm; near IR)	1-1.5	—	0.5-2	1.5	3	0	0.5	0.5	0	2	0-1	2.5	—	—	0-0.5	1-2	1-2	1.2
	11 (1.48-1.85 μm; near IR)	0.5	—	0-1	1	3	0	0.5	0.5	0	2	1-2	3	—	—	0	0-1	0-0.5	0.9
	12 (2.00-2.43 μm; near IR)	0-0.5	—	0-0.5	0.5	3	0	0.5	0.5	0	2	0-1	3	—	—	0	0-0.5	0	0.8
	13-1 (10.20-12.50μm; middle IR)	0-0.5	—	0-0.5	0.5	3	0	0.5	0.5	0	2	1	0	—	—	0	0	0	0.6
1)	4 (0.5-0.6 μm; green)	0.5-2	—	0.5-2	2-3	1	1	4	4	1.5	3.5	0.5	0.5	2	0.5	0.5	0.5	0.5-1.5	1.6
	5 (0.6-0.7 μm; red)	2-2.5	—	2-3.5	3.5	2	3	4	4	1.5	3.5	1-2	1	0	2.5	1-3	1-2.5	2-3.5	2.3
	6 (0.7-0.8 μm; near IR)	2	—	2-3	3.5	3	2.5	4	4	1.5	3.5	2-3.5	1	0	2	1-2.5	1-2	1.5-3	2.4
	7 (0.8-1.1 μm; near IR)	2	—	2-3.5	3.5	3.5	2.5	4	4	1.5	3.5	2-3.5	1	0	2	1-3	1-2.5	1.5-3	2.4

FOOTNOTES:

...larged 3d-generation transparencies of the project region.

...vered scenes from SL 4 mission, Tracks 1 and 58 (see Table 3.)

[3]Better-quality photo images (70 mm and/or 1:1 million-scale formats) of the project region.

[4]See text Table 5 for revised wavelength ranges for the various Skylab spectral bands.

[5]Numerical rating system: 1=poor, 2=fair, 3=good, 4=excellent.

Table 5. Revised determinations of the wavelength ranges for the spectral bands in the S190A multispectral camera array (B/W bands only) and in the S192 multispectral scanner (according to the Sensor Performance Evaluation, Final Report, vol. 1 (S190A), dated May 12, 1975: NASA L. B. Johnson Space Center, Houston, Texas, p. I-43).

S190A			S192	
Station	Band name	Wavelength Band (µm)	Band	Wavelength Band (µm)
			1	0.41 to 0.45
6	B/W green	0.48 to 0.63	2	0.45 to 0.51
			3	0.50 to 0.56
5	B/W red	0.58 to 0.72	4	0.54 to 0.60
			5	0.60 to 0.66
1	B/W IR	0.68 to 0.78	6	0.65 to 0.74
2	B/W IR	0.75 to 0.90	7	0.77 to 0.89
			8	0.93 to 1.05
			9	1.03 to 1.19
			10	1.15 to 1.28
			11	1.55 to 1.73
			12	2.10 to 2.34
			13	10.07 to 12.68

S190B photos are only slightly better in this respect than the S190A photos[4/] -- their sharper resolution commonly slightly overcompensates for the lower base-height ratio caused by the longer focal length of the S190B camera[5/].

[4/] Note in Table 1 that stereorelief detectibility for the better S190A photos is 15-20 m, and for the better S190A phótos, 8-10 m.

[5/] Vertical exaggeration present in a stereoscopic airphoto model is directly related to the base-height ratio. The base-height ratio is controlled by, and inversely related to (a) the focal length of the camera lens, (b) the altitude above the land surface, and (c) the amount of overlap of the airphotos. Thus, the 6-inch focal length of the S190A cameras gives a higher base-height ratio than the 18-inch focal length of the S190B Earth Terrain camera.

Skylab photos were much less successful than the Landsat-1 MSS images in providing enhancement of topographic detail in snow-covered areas. In the Landsat images the enhancement of topography in snow-covered areas commonly is striking (Morrison, 1975; Morrison and Hallberg, 1975). The snow cover masks the distracting tonal differences caused by variations in soils, rocks, and vegetative cover. Also, the low sun-elevation angle characteristic of all winter Landsat images of this region results in shadowing and emphasis of even minor topographic features, akin to a detailed shaded relief map. The enhancement of topographic detail is optimum in regions of low to moderate relief such as the Great Plains-Midwest. Skylab 4 photos provide less shadowing enhancement of topography in the snow-covered areas, for two reasons: (1) the photos were taken near midday, when the sun was near zenith; (2) nearly all the SL4 photos are overexposed for snow-covered areas, particularly the color and CIR bands, because of the relatively small latitude of exposure for these films.

7.0 ANALYTIC GEOMORPHOLOGIC MAPPING

7.1 General considerations

A key means of testing the usefulness of Skylab photos for distinguishing landforms and surficial materials was their use for making maps of "analytic geomorphology." The units shown on these maps stress features that can be determined directly from study of the SL photos, with minimal use of ground control and higher levels of inference. The geomorphic maps were prepared entirely by photointerpretation, without field studies, but using available ground control ranging from topographic maps to geologic and soil maps and reports and high altitude airphotos. This work was done at the USGS facilities at the Denver Federal Center, with Fuller, Muhm, and Prohaska assisting the Principal Investigator.

The objectives for this mapping were (a) to develop and utilize a system for mapping the significant elements of the geomorphology of large parts of the Midwest-Great Plains, in as much detail as possible from the SL photos, and (b) to identify geomorphic anomalies that may reflect local tectonism, remnants of ancient moraines, ice-marginal drainage or other drainage diversions and filled valleys, and other abnormalities in landscape development. Key factors used for differentiating the map units are: (a) land-surface form--with subfactors of slope, local relief, and profile (which will be discussed later), (b) stream density and pattern, and (c) soil characteristics--both soil-color (from the color band) and soil drainage (from the IR bands). Thus, the analytic geomorphology maps are considerably more detailed than the "geologic-terrain" maps prepared from ERTS images of this region--largely because of the superior ground resolution of the Skylab photographs.

The aim of the geomorphic mapping was to map natural landscape units. At the scales of our maps, generally it is not possible to map individual landforms (except the chief valley lowlands); it is necessary to map assemblages of landforms. The assemblages can be distinguished on the basis of the factors listed above, commonly on a semi-quantitative basis. Some boundaries of the landscape units are sharply defined by distinct topographic discontinuities, such as a valley lowland bordered by steep-sided hills, the scarp of a stream terrace, and, commonly, the edge of an upland plateau. Other landscape-unit boundaries are gradational and can be drawn only approximately, at the mid-point of a zone of change in significant landscape factors (e.g., local relief, profile, soil characteristics, etc.).

Systematic mapping and geomorphic analysis of the landforms of this region has hardly begun, although Landsat-1 MSS images were utilized in an earlier project (Morrison and Hallberg, 1975) for mapping gross landscape units. The superior ground resolution and synoptic overviews provided by the Skylab photos make them especially favorable for systematic geomorphic mapping. Such mapping, in the detail and comprehensiveness possible from the Skylab photos, will provide better information on the distribution, nature, and origin of the Earth's natural surfaces. These maps ought to be of value to users such as land-use planners who need accurate characterizations of the landscape; to engineers who require a comprehensive picture of terrain in selecting sites for highways, airfields, waterways, dams, and reservoirs; and to environmentalists who wish to determine the present state of the land and then estimate the consequences of man's projected activities.

A key objective was the identification of discontinuities between landscape units. Continuity of landforms indicates continuity of geomorphic process (Bloom, 1969); conversely, discontinuity of landforms indicates discontinuity of geomorphic process, and thus may be an important clue to details of the history of landscape development. In some cases, landscape discontinuities are indicated by the boundaries between our map units, in other cases, by other types of geomorphic anomalies that will be dicussed later.

Ancillary to the mapping of landform and soil characteristics was the more inferential identification of surficial deposits within the basic geomorphic map units, as well as the identification of various geomorphic/geologic attributes that may be significant for land-use planning and land-resource development. However, the Denver group attempted only very generalized designation of the probable character of surficial deposits and of other aspects of environmental geology within the map units [which are primarily defined on their geomorphic (and soil) characteristics]--conventional mapping of surficial geology or of engineering geology was not our objective. Because we generally had little or no geologic ground control, relatively high degrees of inference were involved in making many of these identifications; consequently, the inferences on surficial materials and environmental geology are stated in very general terms.

Dr. Merlin Tipton, of the South Dakota State Geological Survey, reviewed our analytical geomorphic map of the Sioux Falls study area and commented on our questions about various geomorphic/soil anomalies in the light of available knowledge on the glacial and other surficial deposits. Likewise, Drs. Marvin P. Colson, and Rex Peterson, and other members of the Nebraska Department of Conservation and Survey reviewed and commented on our mapping in the Fremont, Sioux City, Broken Bow, and O'Neill $1^{\circ} \times 2^{\circ}$ quadrangles in NE Nebraska. Dr. William H. Allen, Jr., of the Missouri Division of Geological Survey and Water Resources, evaluated our mapping in the Quincy, St. Louis, and Moberly quadrangles, NE Missouri. In particular, Dr. Jerry A. Lineback, of the Illinois State Geological Survey, not only evaluated our mapping of the Illinois portions of the St. Louis, Quincy, Burlington, and Peoria quadrangles, but also contributed the section in the Appendix of this report "Mapping Illinois geology from space," in addition to preparing a report published by the Illinois Survey (Lineback, 1975).

7.2 Interpretive procedure for mapping analytic geomorphology

Conventional photogeologic techniques were used for the analytic geomorphology mapping, except less emphasis was placed on observing topographic features by stereovision, and more emphasis was given to land-use characteristics. As explained above, the S190A and S190B photos (even the sharper ones) offer only moderate capability for stereoscopic viewing--an average of about 12 to 15 m and at best only 7 m relief detectibility--so many of the finer details of topography cannot be seen unless they are emphasized by differences in vegetation, land use, or shadows. Essential for maximum detail of mapping are both superior sharpness of detail and good gray-scale discrimination (for B/W photos) or hue/chroma/value discrimination (for color and CIR photos). Deficient gray-scale or color discrimination generally is caused by haze degradation and/or by poor exposure or processing.

Somewhat less emphasis was placed on land-use characteristics than was done in the interpretation of ERTS-1 images of this region, because of the better ground resolution and stereorelief of the Skylab photos. The patterns of fields, pastures, woodlands, and rural roads reveal much about topographic details, and hence, about landforms and landform associations. The sizes and shapes (rectangular vs. irregular) of fields are controlled by the topography. Concentrations of very large (greater than 80 to 160 acres) fields with regular shapes and sharp boundaries generally indicate areas of very low relief and low drainage density, such as broad flood plains and flat or gently undulating uplands. Conversely, small, irregular fields show that hills and valleys impose topographic limitations on farming. The distribution of woodlands provides information on the character of valleys and escarpments. In areas of productive soils, woodlands are restricted to slopes too steep to be farmed; in the more arid parts of the region the steeper slopes commonly are partly woodland or brushland and partly pasture. Many rural roads are visible on the images. In areas of low relief, they are straight and rectilinear in pattern, generally following section lines. Bends in the roads commonly indicate valleys with steep slopes; markedly sinuous roads indicate hilly, much-dissected terrain.

However, land-use features can either aid or hinder geomorphic interpretation. Landscape-unit boundaries generally are easy to detect where sharp changes in slope affect land use, for example where a wooded bluff adjoins fields on a valley lowland or upland plateau. Where slopes change gradually, however, the field boundaries may extend across significant "breaks in slope," obscuring the geomorphic boundary. Transitions from nearly level to gentle slopes are very difficult to detect because of this problem, coupled with the limited stereorelief detectibility of the SL photos.

Nevertheless, details of microrelief are well displayed that involve elevation differences that are much smaller than the detectable stereorelief. These details are shown by differences in color (on the color and CIR bands) or tone (on the B/W bands) that presumably are caused by changes in vegetation, soil moisture, and in some cases, field pattern, with slight changes in elevation. Good examples are the mottled appearance of the Wisconsinan drift plains in the Sioux Falls study area.

The limited stereoscopic capability of Skylab photos can be partially overcome by analyzing drainage to interpret relief. Drainage analysis is of great importance because the location and development of streams is determined by variations in resistance to erosion caused by differences in lithology and structure of the underlying bedrock, as well as by surface irregularity produced by deposition and erosion of glacial, alluvial, and eolian surficial materials. Thus, stream density, depth of dissection, type of drainage pattern, and interfluve profile characteristics are important criteria for characterizing the various geomorphic landscape units.

Surficial materials are harder to identify than landforms; generally their interpretation involves secondary and tertiary levels of inference. Key data supplied from the images are landforms, land-use characteristics, and tonal variations indicative of soil conditions, either (1) soil-drainage conditions (best seen in infrared photos taken soon after rains in late fall or spring), or (2) degree of development of soil profiles (best seen in color photos taken in spring). Adequate "ground truth" is essential to control the inferences if a reliable map is to be produced. Sources of ground-control data are published geologic and soil maps, topographic maps, unpublished geologic maps and file data, subsurface data (especially drillhole logs), and field observations by ourselves and our collaborators in the state geological surveys.

7.3 Viewing techniques/procedures for the photointerpretive mapping

We experimented with several techniques and instruments to determine those most efficient and accurate for the evaluative photointerpretive mapping:

(a) Viewing the S190A 70mm and S190B 5-inch unenlarged photos under the B&L zoom stereoscope, at 5 to 20 X magnification. This method is useful for rapid evaluation of photo quality and detection of specific features, but is unsatisfactory for comprehensive mapping because the stereoscope we used lacks a scanning capability.

(b) Projecting S190A 70mm transparencies onto a screen or, preferably, onto either a transparent-film overlay on paper 1^{o} x 2^{o}-quadrangle maps or directly onto 1:250,000-scale green-line prints of these maps on drafting film, using a 2 1/4-inch slide projector. This method is the most practicable for Skylab photos that do not provide stereoscopic coverage, like SL3 Pass 27.The quality of the mapping, however, is inferior to that produced by methods (c) and (e).

(c) Examining the transparency enlargements under an Old Delft magnifying scanning stereoscope at 1.5 or (chiefly) 4.5 X magnification. Most of the maps included in this report were prepared by this method. The interpretive mapping was done on transparent overlays to the 4 X enlargements of the S190A color, CIR, or sometimes the B/W red and B/W farther IR bands, and/or on overlays to the 2 X S190B color enlargements. The quality of the enlargements obviously determines the detail and accuracy of the mapping. Unfortunately, some enlargements are less sharp than they should be and/or are deficient in color balance or contrast. This method is relatively rapid but transfer of data from the overlays to 1:250,000-scale base maps takes considerable time and is likely to result in loss of accuracy because of the nearly 3 X enlargement required.

(d) Viewing S190A color 70mm transparencies with an ER-55 stereoplotter. This instrument provides a less sharp and less well illuminated (very dark) image, with less stereorelief, than the Kern stereoplotter (technique e). Also, although the ER-55 magnifies the image 10 X, its pantograph could not be adjusted to our base-map scale (1:250,000). In addition, the color-viewing headset is noisy and unconfortable to wear.

(e) Using a Kern PG-2 stereoplotter both for interpretation and for plotting data directly onto 1:250,000-scale base maps. Both the 5-inch unenlarged S190B and the 4 X S190A enlargements were used, and the pantograph was adjusted to the 1:250,000 scale of the base maps. The superior optics and illumination of this precision instrument, plus the one-step operation, make this a relatively accurate and efficient method for photointerpretive mapping. The stereoimage can be scanned as readily as with the Old Delft stereoscope and it is sharper and better illuminated. Both mega- and micro-features and relationships can be seen, because each stereomodel covers about 15,500 sq km and can be viewed under various magnifications up to 10 X. The stereomodel from the 4 X color S190A transparencies from SL Track 30 is sharp at 5 X magnification; it begins to lose detail at 10 X but still is useful at this magnification. The model from the 5-inch color S190B transparencies is exceptionally sharp at 5 X magnification--and barely fuzzy at 10 X.

In the July 1, 1974 progress report we stated that where the photos provide stereoscopic coverage, interpretation and mapping are done most efficiently in a single operation using a Kern plotter. This conclusion was based on early studies and is not borne out by later, more extensive ones, using several different photointerpreters. The later experiments used mainly color photos (4 X enlargements of S190A and unenlarged S190B) from SL2, SL3, and SL4 missions for mapping large areas in Nebraska, South Dakota, Iowa, Missouri, and Illinois. They caused us to conclude that the Kern plotter was less advantageous for work with the SL photos than we first believed, for the following reasons:

(1) We used 1:250,000-scale base maps. The overall accuracy of our interpretive mapping does not warrant so large a scale, because of the mediocre stereorelief and fairly moderate ground resolution of the SL photos. The only other standard base maps are at 1:500,000 scale, which is more appropriate--but these maps are of relatively poor photogrammetric quality.

(2) The difficulty and time needed to set up the stereomodel in the Kern plotter makes it generally not feasible to change and compare various spectral bands of the same scene.

(3) Only one Kern plotter was available at USGS in Denver that has a pantograph capable of adjustment to the 1:250,000 scale of the base maps. This plotter was almost continuously in use by other geologists and our access to it was very limited.

We did not experiment with optical enhancement techniques (such as additive color composite made by viewing with a Minniaddcol additive color viewer, "sandwiches" of various bands of the same frame printed on transparent Diazochrome in different color, or electronic density slicing) because our experience with the previous ERTS (Landsat)-1 investigation of this region showed that optical enhancement techniques contribute little or no new information to that given by the unenhanced transparencies.

In conclusion, the final maps given in this report were prepared mostly by technique (c); i.e., by mapping on transparent overlays to the enlarged SL photos (chiefly color, occasionally CIR, B/W red, and B/W farther IR) viewed under an Old Delft scanning stereoscope. In several cases this mapping was supplemented and checked by viewing under the Kern plotter. These techniques were used, of course, only where stereoscopic coverage is available. In some cases additional information was obtained from flights without stereoscopic overlap, either by viewing the transparency enlargements under magnification on a light table and mapping directly on transparent overlays, and/or by projecting the 70mm unenlarged transparencies (using a 2 1/4-inch slide projector) onto 1:250,000-scale "greenline" prints on drafting film of the base maps and drawing the map-unit boundaries on the image on the film.

Stereoscopic viewing of the same scene at different times of year proved invaluable. Spring (SL2) photos are the most suitable because extensive crop growth does not interfere or add unnecessary "noise" to the imagery, especially if one is more interested in mapping soils and surficial geology. Comparison of spring, summer, and winter photos of the same area, however, was very useful.

7.4 Selection of areas for study

For the analytic geomorphic mapping, six general areas were selected for intensive photointerpretive analysis and mapping. The selection was based on meeting as many as possible for the following criteria:

(a) Coverage by good-quality S190A and S190B photos having not more than 30% clouds. The instruments available at the U.S. Geological Survey in Denver for stereoscopic viewing cannot use 70mm transparencies effectively; therefore, good-quality 4 X enlargements are essential.

(b) Stereoscopic coverage (about 60% endlap).

(c) Duplicate coverage, by either approximately coincident or crossing Skylab passes.

(d) Late-spring coverage, at the start of the growing season after plowing of croplands is completed. For this project area, space photos taken at this time of year provide maximum information on geology and soils--consequently, SL2 coverage is preferred over SL3.

(e) Congruence with or partial overlap upon one or more of the 19 areas (mostly $1^{\circ} \times 2^{\circ}$ quadrangles) studied during our ERTS-1 investigation of this region.

(f) Terrain of special environmental-geologic interest to the respective State Geological Surveys.

(g) Terrain of special geomorphic and geologic interest as determined from our own preliminary evaluation of the Skylab photos and/or from our ERTS-1 studies.

Our goal was to apportion the test areas as evenly as possible among the six states. This objective could not be realized fully, however, because of limitations in meeting various of the criteria, especially items (a), (f), and (g). Some states, especially Nebraska, have extensive cloud-free coverage in areas of interest, whereas others, notably Kansas, have little such coverage.

The areas selected for study are of various sizes and shapes because of the irregular distribution of high-quality cloud-free coverage by SL photos (see Fig. A1.1 in Appendix). Generally they include only parts of the following 1^o (latitude) by 2^o (longitude) topographic quadrangles:

Table 6. Study areas and portions of $1^o \times 2^o$ quadrangles included

General study area (Numbers refer to sections in the Appendix in which they are discussed; see Fig. A1.1)	$1^o \times 2^o$ topographic quadrangles (portions) included:
A2 NE Missouri-western Illinois	Moberly, Quincy, St. Louis, Jefferson, Centerville
A3 SE South Dakota-NW Iowa	Sioux Falls
A4 NE Nebraska and western Iowa	Broken Bow, Fremont, O'Neill, Sioux City, Omaha, Nebraska City
A5 Central and southern Illinois	Belleville, Burlington, Davenport, Decatur, Paducah, Peoria

A total of about 163,000 sq km were mapped, at scales ranging from about 1:713,000 (the scale of the S190A 4 X enlargements) to 1:250,000.

7.5 Ground-control information

Ground control for the analytic geomorphology mapping was chiefly from topographic quadrangle maps ($1^o \times 2^o$), supplemented where possible by 15-and 7 1/2-minute quadrangle maps. The entire region is covered by $1^o \times 2^o$ maps; coverage of our study areas by 15 and/or 7 1/2-minute maps (1:62,500 and 1:24,000 scale) ranges from 100% in Illinois, Kansas, and Missouri, to about 95% in Nebraska, and to about 60% in Iowa and South Dakota. Such maps give important information on landforms but little on geology. All the study areas are covered by maps of bedrock (pre-Quaternary) geology at 1:500,000 or larger scales, but these maps either ignore or minimize the surficial (Quaternary) geology. Available (mostly published) up-to-date comprehensive maps of surficial deposits at scales larger than 1:500,000 provided about 60% coverage of our study areas in Illinois and Kansas, about 20% in South Dakota, and less than 5% in Iowa, Missouri, and Nebraska—a net average coverage of less than 25% of the entire area we mapped. None of the study areas was completely covered by large to intermediate-scale maps of surficial deposits. Coverage by geomorphic maps of 1:500,000 or larger scale is negligible. Soil maps provide complete or nearly complete coverage of many study areas, but they proved to be generally of limited value for interpretation of surficial geology and geomorphology.

Important additional information also was provided in several areas by high-altitude airphotos taken by NASA for the earlier ERTS-1 project and for this project, as follows (Fig. 2):

Figure 2.--NEAR HERE

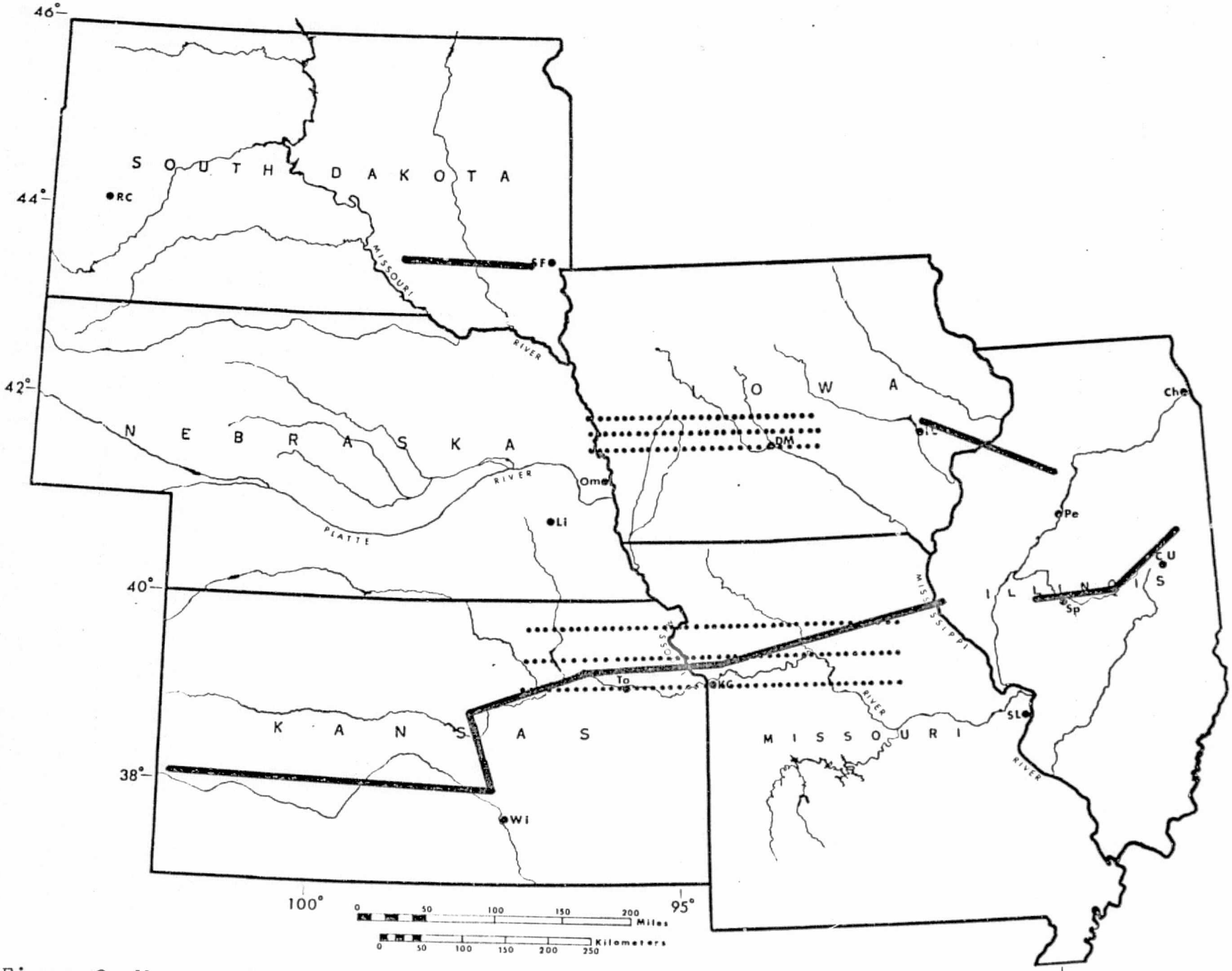

Figure 2. Map showing flight lines of NASA U-2 (heavy solid lines) and WB-57 (dotted lines) aircraft for color and color-infrared photographs taken for this project

1) One U-2 flight line covered about 2,160 sq km in the west-central part of the Sioux Falls study area in CIR (2443 film) at ca. 1:125,000 scale.

2) A single U-2 flight line covered about 830 sq km in the northwestern part of the NE Missouri study area, also in CIR (2443 film) at ca. 1:125,000 scale.

3) Three WB-57 flight lines (not overlapping) covered much of the western part (ca. 5,200 sq km) of the NE Missouri study area, in both color (2445 film) and CIR (2443 film) at ca. 1:120,000 scale.

4) Three WB-57 flight lines (overlapping) covered the entire north half of the Omaha study area (ca. 5,800 sq km), also in both color (2445 film) and CIR (2443 film) at ca. 1:120,000 scale.

7.6 Land-surface-form factors

A primary objective for our geomorphic mapping was to develop a matrix for describing the most significant elements of land-surface form for characterizing different landscape units in this region (in terms identifiable from the SL photos) as objectively and quantitatively as possible. We wished to have the smallest possible number of categories and subcategories that will provide the necessary degree of sensitivity for distinguishing geomorphic discontinuities and anomalies peculiar to this region. Several different matrix models of descriptive/analytic factors were tried out before the matrix described here was adopted. The matrix we finally chose is derived from that developed by E. H. Hammond for the Land-Surface Form maps in the National Atlas of the United States (Hammond, 1966). Hammond uses 3-item symbols to distinguish three main properties of land-surface form: slope, local relief, and profile type. We retained Hammond's four-fold division of the slope factor without change, but the subdivision of the local-relief and profile-type factors required modification in order to be suitable for the limited ranges of local relief and profile type in the Great Plains-Midwest, and provide the sensitivity necessary to reveal geomorphic discontinuities in this region . Table 7 compares Hammond's and our subdivision of these factors.

Table 7.--NEAR HERE

For the slope factor, we adopted Hammond's definition of gentle slope, namely, an inclination less than 8% ($4^{\circ}34'$). This limit, according to Hammond (1966), falls "in the range within which the difficulty of machine cultivation increases rapidly, erosion of cultivated fields becomes troublesome, easy movement of vehicles becomes impeded, and in general one becomes highly conscious that he is dealing with a sloping surface."

Local relief is defined as the maximum difference in elevation within a local area. Hammond used a unit area of six miles across for his US map. We used unit areas of one to two miles on a side for our maps, depending on the complexity of relief and detail visible on the SL photos. We adopted much smaller elevation ranges for subdivisions of local relief than those used by

Table 7. Our subdivision of the factors of land-surface form compared with the subdivision made by E. H. Hammond for the Land-Surface Form map of the United States (published in the U.S. National Atlas).

Hammond's subdivision for the Land-surface-form map of the United States:	Our subdivision for the Analytic Geomorphology maps interpreted from Skylab photos	Our subdivision for Land-surface-form maps prepared (as ground control) from 7 1/2-minute topographic quadrangle maps
	SLOPE (Capital letter)	
A More than 80% of area gently sloping	(Identical with Hammond's)	(Identical with Hammond's)
B 50-80% of area gently sloping		
C 20-50% of area gently sloping		
D Less than 20% of area gently sloping		
	LOCAL RELIEF/DEPTH OF DISSECTION (Arabic numeral):	
1 0-100 feet	1 < 30 m (< 100 ft)	1 < 75 ft (< 23 m)
2 100-300 feet	2 30-60 m (100-200 ft)	2 75-150 ft (23-45 m)
3 300-500 feet	3 > 60 m (> 200 ft)	3 150-225 ft (45-68 m)
4 500-1,000 feet		4 225-300 ft (68-90 m)
5 1,000-3,000 feet		5 > 300 ft (> 90 m)
6 Over 3,000 feet		
	PROFILE TYPE (lower-case letter; for uplands and plains other than valley lowlands)	
a More than 75% of gentle slope is in lowland	a Undissected plains: Flat to gently undulating, without appreciably entrenched stream valleys (slope class A).	
b 50-75% of gentle slope is in lowland	b Slightly dissected plains: Wide flat to gently sloping interfluves; few, widely spaced valleys (slope classes A and B).	
c 50-75% of gentle slope is on upland	c Hilly uplands, moderately dissected, with many gently sloping interfluve plateaus (slope classes B and C).	
d More than 75% of gentle slope is on upland	d Hilly uplands, much dissected, with some to few gently sloping interfluves (slope class C).	
	e Hilly uplands, highly dissected; no gently sloping interfluves (slope class D).	

Hammond, because local relief in the Great Plains-Midwest rarely exceeds 100 m. Only three subdivisions of local relief (see Table 7) were made for the maps interpreted from the SL photos, because the limited capability of the photos for determining stereorelief does not warrant finer subdivision. Five subdivisions were used for the land-surface form maps prepared from 7 1/2-minute topographic quadrangles.

We also adopted a five-fold subdivision of profile type that differs considerably from Hammond's four-fold subdivision, because our map units are much smaller than Hammond's (our map scales are an order of magnitude larger). Our subdivisions are designed to distinguish the more important differences in profile type found in the Great Plains-Midwest.

7.7 Land-surface form maps compiled from 7 1/2-minute quadrangle topographic maps

For evaluating the accuracy of the photointerpretive mapping of land-surface form from the SL photos, two relatively detailed maps of land-surface form were prepared by somewhat generalizing the topographic information available from 7 1/2-minute topographic quadrangle maps and plotting this information on 1:250,000-scale $1^{\circ} \times 2^{\circ}$ quadrangle maps. The two $1^{\circ} \times 2^{\circ}$ maps made in this manner are the Fremont quadrangle (Nebraska, for which coverage by 7 1/2-minute quads is complete) and the Sioux Falls quadrangle (South Dakota, which is about 60% covered by 7 1/2-minute topographic maps). These maps were prepared by outlining in heavy lines on the various 7 1/2-minute topographic maps the various land-surface-form units, then photographing these maps using a Hasselblad camera, so that the scale of the photo negative is exactly 1:250,000, and then directly tracing the boundaries from the negative onto a superposed greenline mylar transparency of the 1:250,000-scale $1^{\circ} \times 2^{\circ}$ base map.

7.8 Environmental landscape units used for the analytic geomorphology maps

Although several key attributes were noted as a basis for distinguishing between the landscape map units, no attempt is made to show these attributes by means of complex map symbols. Instead, the map symbols for the analytic geomorphology maps are restricted to 1, 2, or 3 characters in order to keep the symbols simple and easy to read. (The specific map explanations for each study area characterize each map unit in detail.)

A standard map explanation was developed (Table 8), that is applicable to all the types of analytic geomorphology maps, in all the study areas in this region. The distinction of landscape map units is based on the following hierarchy of distinguishing characteristics (which are indicated in the map symbols themselves:

Map symbol hierarchy	Distinguishing characteristics
1 (Arabic numeral)	Major landscale category (on the basis of morphogenesis and dissection)
2 (1st small letter, where needed)	Profile detail _or_ surficial cover _or_ morphogenetic type
3 (2d small letter, where needed)	Surficial cover _or_ morphogenetic type

7.9 Comparison with geologic-terrain interpretations from Landsat (ERTS)-1 images

For comparison with the mapping of geologic-terrain units from Landsat (ERTS)-1 images, two maps are included that were prepared during the previous ERTS-1 investigation in this region (Morrison and Hallberg, 1975). Figure 3 includes part of the northeastern Missouri study area discussed in Appendix section A2, and also part of the northeastern Nebraska-western Iowa study area, discussed in Appendix section A4. Figure 4 includes the Sioux Falls study area in South Dakota, discussed in Appendix section A3. The greater detail of mapping achieved from the SL photos should be readily apparent.

Table 8--NEAR HERE
Figure 3.--NEAR HERE
4.--NEAR HERE

Table 8. Standard map explanation for the analytic geomorphology maps

Environmental landscape units

Map Unit	
1	Alluvial lowlands, undifferentiated (local relief < 15 m)
1 f	Lower terraces and Holocene flood plains
1 t	Higher stream terraces (Wisconsinan or older)
1 o	Glacial outwash terraces, channels, and plains
2	Plains, nearly flat to gently rolling, few streams, shallow dissection (local relief generally < 15 m)
2 l	Underlain chiefly by loess of late Wisconsinan age; well-drained soils
2 ll	Underlain chiefly by young and older loess
2 c	Underlain chiefly by older loess (and till locally); poorly drained soils
2 m	Underlain chiefly by till of the last glaciation; soils mostly poorly drained
2 g	Underlain chiefly by till of the last glaciation; soils mostly poorly drained; ground moraine
2 s	Underlain chiefly by till of the last glaciation; soils mostly poorly drained; stagnation moraine
3	Gently rolling hills; local relief < 30 m, generally < 20 m stream density moderate, dissection shallow to moderate
3 l	Cover of young loess dominant, well-drained soils
3 c	Cover of older loess dominant and/or till, soils commonly poorly drained
3 b	Bedrock at or close to surface

Map Unit	
4	Upland plains, moderately dissected, local relief generally ≤ 30 m
4 b	Interfluves gently rolling
4 be	Interfluves gently rolling, cover of loess dominant
4 c	Many flattish interfluves
4 cl	Many flattish interfluves, cover of young loess dominant
4 cc	Many flattish interfluves, cover of older loess and/or till locally dominant (poorly drained soils common)
4 d	Some flattish interfluves
4 dl	Cover of young loess dominant
4 dc	Cover of older loess and/or till dominant
4 e	Few to no flattish interfluves
4 el	Cover of young loess dominant
4 ec	Cover of older loess and/or till dominant
5	Uplands, deeply dissected; local relief 30-60 m
5 b	Interfluves gently rolling
5 be	Interfluves gently rolling, cover of loess dominant
5 c	Many flattish interfluves
5 cl	Cover of young loess widespread
5 cc	Cover of older loess and/or till widespread
5 d	Some flattish interfluves
5 dl	Cover of young loess widespread
5 dc	Cover of older loess and/or till widespread
5 e	Few or no flattish interfluves
5 el	Cover of young loess widespread
5 ec	Cover of older loess and/or till widespread

Map Unit	
6	**Uplands, very deeply dissected, local relief > 60 m**
6 b	Some rounded interfluves
6 d	Some flattish interfluves
6 dl	Loessial cover prominent
6 dx	Mixed surficial cover
6 db	Mixed surficial cover over bedrock
6 e	Few or no flattish interfluves
6 el	Loessial cover prominent
6 ex	Mixed surficial cover
6 eb	Mixed surficial cover over bedrock
7	**Bluffs and escarpments, highly dissected**
7 a	Local relief < 30 m
7 b	Local relief 30-60 m
7 c	Local relief > 60 m
8	**Dune areas**
8 u	Mainly U-shaped (longitudinal) dunes, commonly higher than 15 m
8 ua	Mainly U-shaped (longitudinal) dunes, but local relief generally < 15 m
8 m	Mixed dunes forms, partly longitudinal, partly irregular, generally low (< 20 m) and commonly poorly developed.
8 i	Irregular dunes, dune forms commonly distinct, generally < 15 m high; fairly continuous eolian sand cover
8 ii	Irregular dunes, dune forms commonly indistinct and/or much eroded, generally < 15 m high.
8 id	Irregular dunes, dune forms commonly indistinct and scattered; discontinuous eolian sand cover
8 d	Deflation hollows and plains, commonly with scattered low dunes, generally < 15 m high.

Special symbols

T Glacial kame

U Urbanized (built-up) area

M Strip mine, clay or sand/gravel pit, or rock quarry

K Karst (limestone sink-hole) topography

W Lake, pond, reservoir, or large flowing stream

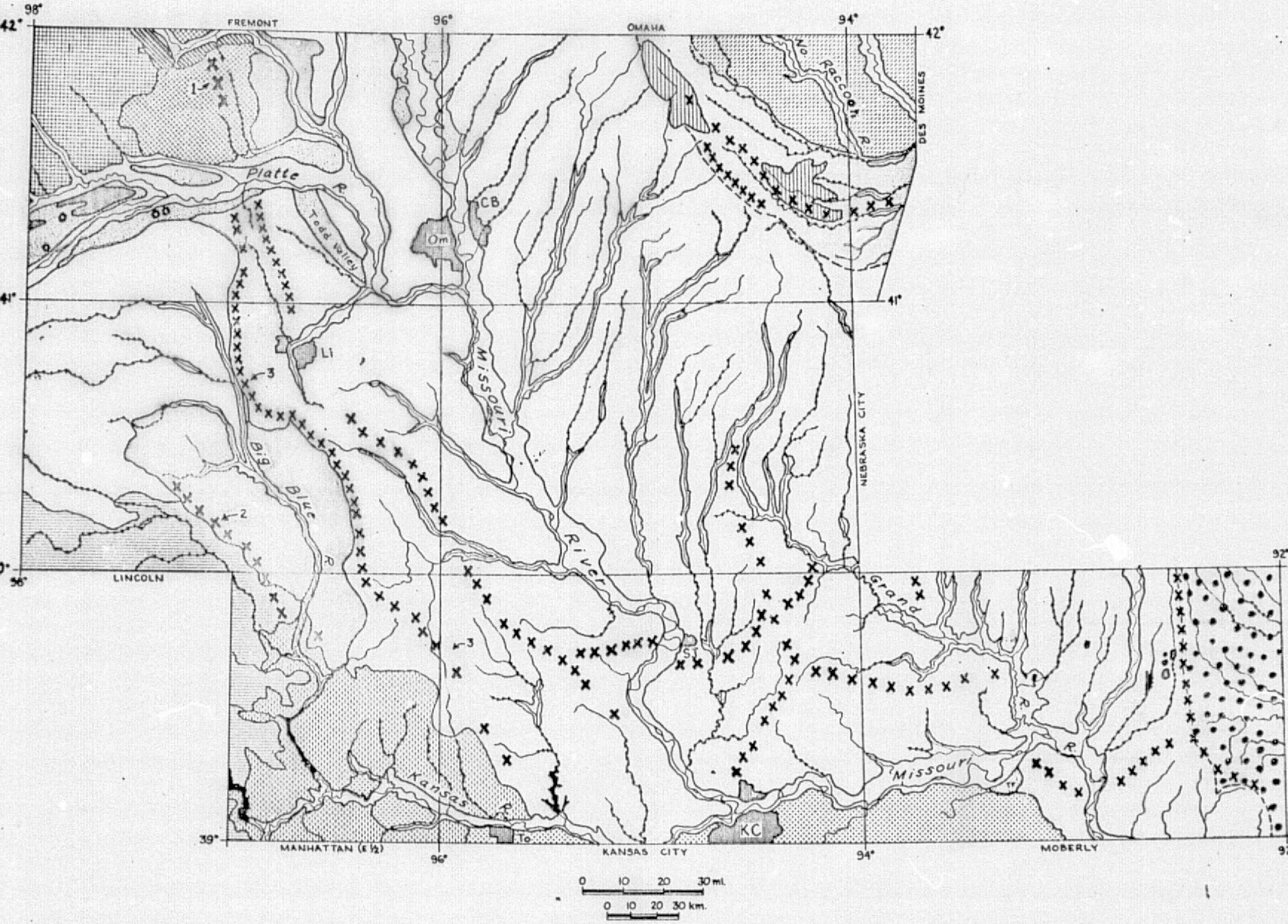

Figure 3. Landsat-1 map of the Des Moines (W part), Omaha, Fremont, Lincoln, Nebraska City, Manhattan (E½), Kansas City, and Moberly 1°× 2° quadrangles, Iowa, Nebraska, Kansas, and Missouri.

Figure 3. Landsat-1 map of the Des Moines (W part), Omaha, Fremont, Lincoln, Nebraska City, Manhattan (E½), Kansas City, and Moberly 1°× 2° quadrangles, Iowa Nebraska, Kansas, and Missouri.

Map Explanation

MAP UNIT	LANDFORM CHARACTERISTICS	LAND-USE CHARACTERISTICS	SURFICIAL-GEOLOGIC MATERIALS
		LOWLANDS	
1a.	Valley lowlands. Flood plains and low terraces. Nearly flat lowlands along larger streams. Oxbow lakes, meander scars, and point-bar deposits are common. IR reflectance generally is lower than in surrounding uplands, especially in spring images.	Fields moderate to large, regular in shape, except adjoining channels, where they become irregular, poorly defined, and give way to pasture and woodlands. Includes parts of the major urban areas.	Alluvial sand, gravel, and silt, locally mantled by loess on terraces (late Quaternary). On IR images, tones lighten toward present channels, indicating coarser, better-drained alluvial soils.
1b.	Valley lowlands distinguishable on ERTS images but too narrow to map in detail.		
1c.	Terraces along the Platte and Missouri Rivers. Nearly level to undulating, relief generally less than 50 ft (15 m), except at margins with unit 1a, where local relief may be as much as 100 ft (30 m). Includes Todd Valley, an abandoned channel of the Platte River (Fremont quad) and Tetsau Flats (TF) along the Missouri River (Moberly quad).	Fields moderate to large, regular in shape; some rangeland.	Loess, and in places, eolian sand over glacial outwash sand and gravel (Wisconsinan). On IR images, slightly darker toned than surrounding uplands but lighter than unit 1a.
		SAND DUNES	
2a.	Low sand dunes on terraces of the Platte River (Fremont quad). Swell and swale topography but no well-formed dunes. Local relief less than 50 ft (15 m). O indicates small isolated areaof such dunes.	Predominatly rangeland; some center-pivot irrigated fields appear as small dark circles.	Eolian sand and local loess over glacial outwash sand and gravel (late Quaternary). Mottled appearance attests to variable soil-drainage and vegetation differences.
2b.	Sand dunes on moderately dissected older terraces. Local relief 50 to 150 ft. (15 to 45 m).		Eolian sand and local loess over alluvial sand and gravel of middle Pleistocene (Illinoian and older) age.
		YOUNG TILL PLAIN WITH LITTLE OR NO LOESS COVER	
3.	Wisconsinan till plain. Undulating plain with local relief generally less than 50 ft (15 m) but as much as 200 ft (60 m) where main streams have cut through end-moraine ridges. Mostly end moraines, some ground moraine. Drainage is poorly integrated and moraine-controlled. Dissection is less than on the Kansan till plain.	Mostly cropland; fields moderate in size and regular in shape. Woodlands locally along streams where slopes are steepest and also bordering stream channels.	Clayey till (late Wisconsinan) with little or no loessial cover. Darker tones on spring IR images attributed to poorer drainage of these soils compared to those of the Kansan till plains.
		OLDER TILL PLAINS WITH LOESSIC COVER	
4a.	Younger Kansan till plain. Moderately dissected plains of higher elevations and higher relief (200 feet, 60 meters) than unit 2. Streams entrenched and alinements appear to have been controlled by a series of former end moraines, in an arcuate pattern paralleling the Bemis moraine to the north. Major streams have narrow flood plains.	Fields moderate in size and regular in shape. Woodlands (dark-toned on red band in summer) common along entrenched streams.	Widespread loessic mantle (late Quaternary) over glacial drift (late Kansan). Bedrock (limestone, shale, some sandstone, upper Paleozoic and Cretaceous) exposed in places along stream valleys. Lighter tones on spring IR images indicate generally better-drained soils than in unit 2.
4b.	Dark-toned younger Kansan till plain. Two separate areas within unit 3a and darker toned on spring IR imagery. Less dissection and lower relief (50-150 feet, 15-45 meters) than unit 3a. Few entrenched streams. No flood plains evident on ERTS imagery.	Fields larger in size than unit 3a and regular in shape. Woodlands along entrenched streams.	Like 3a, except darker tones in spring IR images indicate soils generally are more poorly drained.
4c.	Older Kansan till plain. Streams closely spaced and well entrenched, with moderately wide to narrow interfluves. Local relief commonly 150-200 ft (45-60 m), but as much as 350 ft (105 m) along the Missouri River bluffs, where dissection in places is so intricate as to resemble badlands. Most streams have flood plains, many of which are wide enough to be mapped from ERTS images. Drainage patterns generally do not suggest control by former end moraines; however, in a few places, possible relicts of end moraines are inferred from divide relationships, arcuate drainage patterns, and linear tonal anomalies. Notable are the Clarkson (1), and Cedar Bluffs (2) relict end moraines in Nebraska and Kansas.	On flatter uplands, fields are mostly small and regular-shaped; on slopes they become irregularly shaped, and the steeper slopes commonly are wooded. Abundance of rangeland increases westward from the Missouri River.	Widespread loessic mantle of late Quaternary (Wisconsinan and Illinoian) age, thickest along Missouri River bluffs and thinning eastward; overlies glacial drift of Kansan and locally Nebraskan age. Local bedrock outcrops (limestone, shale, and sandstone of Paleozoic and Cretaceous age) along stream valleys. Uplands appear light-toned on spring IR images, indicating better-drained soils than in the lowlands.
4d.	Old till plain, moderately dissected, intermediate between units 3a and 4e. Uplands are tabular, relatively wide and gently undulating; valleys are moderately spaced and moderately entrenched. Local relief generally is less than 100 ft (30 m).	Uplands mainly dry-land cropland and pastureland, fields moderate in size and regular in shape; some rangeland, indicated by absence of field patterns.	Widespread loessic mantle (late Quaternary) over glacial drift (middle Quaternary). Bedrock (shale, sandstone, and local limestone, Cretaceous) is exposed in places along deeper valleys.

Figure 3. Landsat-1 map of the Des Moines (W part), Omaha, Fremont, Lincoln, Nebraska City, Manhattan (E½), Kansas City, and Moberly 1°× 2° quadrangles, Iowa, Nebraska, Kansas, and Missouri.

Map explanation, continued.

MAP UNIT	LANDFORM CHARACTERISTICS	LAND-USE CHARACTERISTICS	SURFICIAL-GEOLOGIC MATERIALS
	OLDER TILL PLAINS WITH LOESSIC COVER (Continued)		
4e.	Upland plain, moderately dissected; valleys closely spaced, moderately entrenched; inter-stream uplands narrow; local relief commonly about 150 ft (45 m). Lighter-toned than unit 5d.	Fields small to moderate in size, regular in shape; a few are irrigated by center-pivot systems. Large areas of range-land.	Widespread loessic mantle (late Quaternary) over glacial drift (middle Quaternary). Bedrock (shale, sand-stone, and local limestone, Cre-taceous) is exposed in places along deeper valleys.
4f.	Upland plain, with moderately spaced and en-trenched valleys, broad gently undulating divides; local relief generally less than 150 ft (45 m).	Fields large and regular on the broad uplands, moderate to small and irregular elsewhere; wood-lands on steeper slopes and along streams.	Mantle of loess over till of middle and locally early Pleistocene age; bed-rock (mainly limestone and shale, Pa-leozoic) exposed in places in valleys.
	LOESS-MANTLED PLAINS BEYOND THE GLACIAL LIMIT		
5a.	Plains with broad, gently undulating uplands; valleys widely spaced and shallow; local relief generally less than 50 ft (15 m), locally as much as 100 ft (30 m) along entrenched streams.	Mostly cropland, some rangeland. Fields moderate to large in size, regular in shape. Some circular center-pivot irrigated fields.	Widespread loessic cover of late Quaternary (Wisconsinan and Illinoian) age, over alluvium of middle Pleisto-cene age. Bedrock (shale, sandstone, and limestone of Cretaceous age) is exposed only along the more deeply entrenched streams.
5b.	Like 4e except generally darker-toned on spring IR images.	Like 4e.	
	WELL-DISSECTED UPLAND PLAINS WITH LITTLE OR NO SURFICIAL MANTLE		
6a.	Hilly, well-dissected upland plain; valleys closely spaced, moderately entrenched except deeply entrenched along Missouri River); interfluves moderately wide to narrow; local relief generally less than 100 ft (30 m), increasing to as much as 350 ft (105 m) near Missouri River. Darker-toned than most of unit 3c.	Mainly pasture; steeper slopes commonly wooded; croplands concentrated along lowlands.	Discontinuous loessic cover over patchy alluvium and glacial deposits of middle Pleistocene (Kansan) age. Bedrock (mainly limestone, some shale and sandstone, of late Paleozoic age) is widely exposed.
6b.	Hilly, highly dissected upland plains; streams closely spaced and moderately to deeply entrenched; local relief generally less than 250 ft (75 m).	Mostly rangeland; few fields evident.	Patchy loess (later Quaternary), alluvial sand and gravel, and near northeastern border, glacial drift (middle Pleistocene). Bedrock (shale and limestone, late Paleozoic) is widely exposed but commonly has a thin mantle of colluvium. Western boundary is marked by a west-facing escarpment formed by massive limestone (Permian).
6c.	Like 6b.		Bedrock (mainly shale and limestone, some sandstone, late Paleozoic and locally Cretaceous) is widely exposed, albeit commonly mantled with thin colluvium on slopes. Interfluves have patchy mantle of loess (late Qua-ternary), alluvial sand and gravel (middle and locally early Quaternary), and, in extreme eastern part, glacial drift (middle Quaternary).
7.	Urban areas of Topeka (To), Kansas City (KC), Saint Joseph (SJ), Lincoln (Li), Omaha (Om), and Council Bluffs (CB).		
8.	Lake or reservoir.		
9.	Strip mine.		
O 10.	Small isolated area of sand dunes.		
XXX 11.	Known or possible moraine-controlled divides of Kansan age. Erosion has removed the original morainal morphology, and, in some cases, all traces of till. Numbers denote the Clarkson (1), Cedar Bluffs (2), and Nickerson (3) relict end moraines.		

ERTS-1 IMAGES USED:

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1023-16442 8/14/72	1058-16392 9/19/72	1096-16503 10/27/72	1185-16452 1/24/73	1273-16342 4/22/73	1329-16445 6/17/73
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1055-16215 9/16/72	1073-16215 10/4/72	1128-16282 11/28/72	1237-16340 3/17/73	1274-16400 4/23/73	1346-16392 7/4/73
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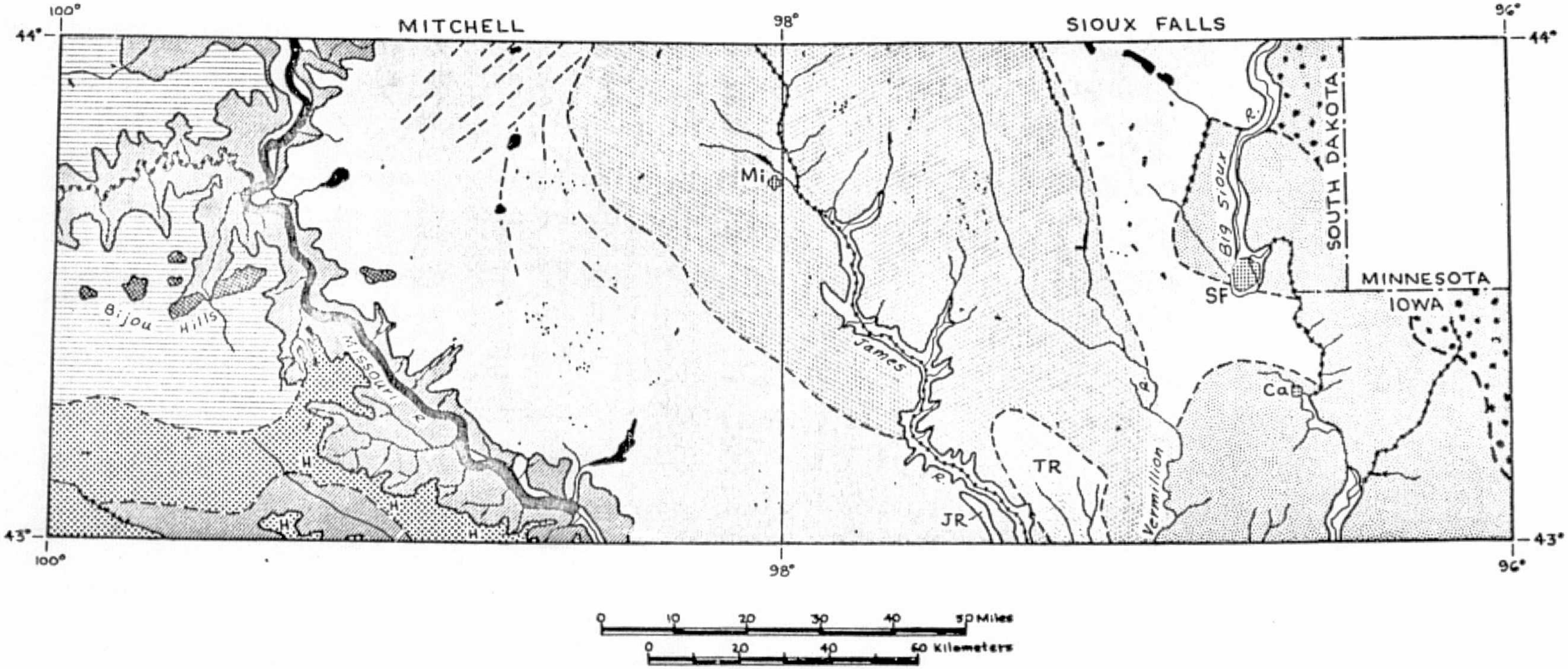

Figure 4. Landsat-1 map of the Mitchell and Sioux Falls 1°× 2° quadrangles, South Dakota and Iowa.

Figure 4. Landsat-1 map of the Mitchell and Sioux Falls 1°× 2° quadrangles, South Dakota and Iowa.

Map Explanation

MAP UNITS	LAND-USE CHARACTERISTICS	LAND-USE CHARACTERISTICS	SURFICIAL-GEOLOGICAL MATERIALS	SIGNIFICANT ENVIRONMENTAL-GEOLOGIC ATTRIBUTES[1]
		LOWLANDS		
1a.	Valley lowlands. Flood plains and low terraces along major streams.	Fields moderate to large in size, regular in shape; considerable pastureland. Dark-toned in summer red-band images due to cropland vegetation.	Alluvial sand, gravel, and silt; locally mantled by loess on terraces.	Important shallow aquifers; good sand/gravel deposits; excavation easy; foundation conditions good to poor; no topographic limitations for road construction; flood plain portions subject to recurrent inundation
1b.	Valley lowlands. Distinguishable on ERTS images but too narrow to map in detail.			
		BLUFFS		
2a.	Highly dissected bluffs and badlands of the Missouri, White, Bad, and Keya Paha Rivers. Local relief as much as 600 ft (180 m) along the Missouri River. Tributaries of main rivers are short ravines (locally called "breaks"), with very steep gradients. Landslide features are common.	Rangeland and wasteland, partly wooded.	Predominately Pierre shale (Cretaceous) which is weakly resistant to erosion. Upland divides locally are veneered by alluvial gravel of early Pleistocene (?) age. Niobrara limestone (resistant, Cretaceous) exposed in lower elevations of the Missouri and White River trenches.	Excavation generally easy; foundation conditions generally poor, except fair to good on gravel-covered upland divides; widespread shrink-swell soil/rock conditions; potential and active landslumps in many places; surface drainage good, subsurface drainage generally poor; severe topographic limitations for road construction; areas of scenic interest.
2b.	Highly dissected bluffs of the James River and its tributaries. Local relief 100-150 ft (30-45 m).	Rangeland and wasteland. Uniform-toned on ERTS images.	Glacial tills of late and middle Pleistocene age, thinly mantled with loess.	
		YOUNGER (WISCONSINAN) TILL PLAIN		
3a.	End and stagnation moraines. Level to rolling plains with generally less than 100 ft (30 m) of local relief. Lower than Illinoian till plain (unit 4). Drainage is poorly integrated; streams are few and their valleys shallow; many small closed or poorly drained depressions. Numerous ponds and lakes, mostly small, shallow, and temporary, and, in places, saline, especially in southwestern part. A few large lakes. Depressions occupied by lakes were caused partly by collapse after melting of stagnant ice, by moraine-damming of earlier valleys, and by other morainic control. Kame hills are common. Includes western part of Coteau des Prairies and the Coteau du Missouri. Linear tonal boundaries indicating morainal linears are shown by dashed lines.	Fields generally moderate in size and regular in shape, but larger in poorly drained areas, where cropland gives way to range and pasture.	Thin loess over clayey till of late Wisconsinan age, commonly less than 50 ft (15 m) thick, but locally as much as 400 ft (120 m) thick. Also includes local outwash-channel and ice-contact (kame) deposits of gravel and sand.	Excavation easy; foundation conditions good to poor; surface drainage good to poor, many poorly-drained or closed depressions; subsurface drainage generally fair to poor, locally good in gravelly outwash channels and kame hills; the outwash channels are aquifers and they and the kame hills are good sources of gravel; few topographic limitations for road construction.
3b.	Ground moraine and a few small end moraines, deposited by the James River glacial lobe in late Wisconsinan time. Elevations lower and local relief less than unit 3a (mostly less than 30 ft, 9 m). Smoothly rolling plain with broad, low divides, without distinct morainic ridges. Stream dissection shallow, but better integrated than unit 3a. Lakes common, but smaller than in unit 3a.	Fields moderate in size but smaller than in unit 3a; regular in shape.	Thin loess over till as much as 300 ft (90 m) thick. Some sand and gravel outwash and ice-contact deposits.	
3c.	Similar to 3b; soils generally somewhat more poorly drained.		Loess over till of early Wisconsinan age.	
		OLDER (ILLINOIAN) TILL PLAIN		
4.	Illinoian till plain. Compared with the Wisconsinan till plain (units 3a and 3b), elevations are higher, local relief is greater (commonly more than 100 ft, 30 m), because the streams are moderately entrenched. The drainage pattern is also denser and well integrated. Interfluves are fairly narrow and flat to rounded.	Fields generally larger than in units 3a and 3b; regular in shape. Some rangeland on steeper slopes.	Till of Illinoian age with a loess mantle, over bedrock (Niobrara Fm., Cretaceous). Soil drainage better than on Wisconsinan till plain as evidenced by lighter tones on IR images.	Excavation easy; foundation conditions and surface/subsurface drainage generally fair to good; few to moderate topographic limitations for road construction.

Figure 4. Landsat-1 map of the Mitchell and Sioux Falls 1°× 2° quadrangles, South Dakota and Iowa.

Map explanation, continued.

MAP UNITS	LANDFORM CHARACTERISTICS	LAND-USE CHARACTERISTICS	SURFICIAL-GEOLOGIC MATERIALS	SIGNIFICANT ENVIRONMENTAL-GEOLOGIC ATTRIBUTES[1]
		HILLS		
5a.	Drift-mantled hills. Includes Turkey Ridge (TR) and James Ridge (JR); also called James River Highlands. These were pre-glacial bedrock drainage divides that were overridden by ice and left with a variable thickness (30-200 ft, 9-60 m) of till. End moraines are alined in concentric bands around Turkey Ridge. Two streams that flow south along the axis of Turkey Ridge probably originated as ice-marginal channels when ice surrounded this highland.	Fields small to moderate in size, regular to irregular in shape, depending on slope. Some rangeland.	Till of Wisconsinan age over bedrock (Niobrara limestone and Pierre shale, Cretaceous). Lighter tones on IR imagery indicate better-drained soils than surrounding till plains.	Excavation generally easy to fairly easy, but in places in bedrock moderately difficult; foundation conditions good, fair, to locally poor; surface drainage good; subsurface drainage good to poor; moderate topographic limitations for road construction.
5b.	Bedrock hills. Erosional remnants, some with a resistant caprock, rising as much as 400 ft (120 m) above surrounding plains. Alinement of the hills, the caprock, and near-accordance of summits suggests that these hills may be relicts of a late Tertiary (?) west-east-flowing river system.	Entirely rangeland, no fields.	Pierre shale (Cretaceous) with a resistant sandstone and quartzite caprock (Ogallala Fm., Tertiary).	Excavation moderately difficult in caprock, fairly easy in Pierre shale; foundation conditions good on caprock, generally poor on shale, where shrink/swell soil/rock conditions are common, as well as active and potential landslumps; surface drainage good; subsurface drainage generally poor; severe topographic limitations for road construction; areas of scenic interest.
		LOESS-MANTLED PLATEAUS		
6a.	Pierre Hills. Gently rolling plain with shallow to moderate dissection (greater than in unit 6b) and local relief of 50-200 ft (15-60 m). Extensive eolian deposits have distinctive alinement oriented northwest to southeast, revealed in the parallel drainage. Eastern part was glaciated, but no expression of this is seen on the ERTS imagery.	Fields moderate to large in size; regular in shape, except smaller and irregular on steeper slopes.	Loess-mantled Pierre shale (Cretaceous), which is weakly resistant to erosion. Some thin patchy glacial drift (of early Wisconsinan age) near Missouri River trench.	Excavation generally easy; foundation conditions good to poor; surface drainage generally good, subsurface drainage fair to locally poor; moderate to severe topographic limitations (across valleys) for road construction.
6b.	Benchlands. Flat to gently rolling uplands with less dissection and lower local relief (less than 100 ft, 30 m) than unit 6a, although elevations are higher. Interfluves are broad and flat. Some small closed basins. Cemented, resistant sediments form a caprock responsible for the plateau-like surface and the escarpments surrounding it.	Mostly rangeland with some small fields.	Loess-mantled resistant quartzite and sandstone (Ogallala Fm., Tertiary) capping weakly resistant Pierre shale (Cretaceous). Local alluvial gravel cappings (Herrick Gravel, early Pleistocene(?)) are indicated by (H).	Excavation easy in surficial mantle, fairly easy in Pierre Shale, moderately difficult in caprock; foundation conditions and surface/subsurface drainage good to fair, locally poor; gravel deposits locally; few to locally moderate topographic limitations for road construction.
7.	Lakes and reservoirs.			
8.	Urban areas of Sioux Falls (SF), Canton (Ca), and Mitchell (Mi).			

ERTS-1 IMAGES USED:

1043-16550 9/4/72	1114-16500 11/14/72
1043-16552 9/4/72	1114-16502 11/14/72
1044-17004 9/5/72	1185-16443 1/24/73
1060-16491 9/21/72	1186-16501 1/25/73
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1061-16552 9/22/72	1241-16561 3/21/73
1076-16382 10/7/72	1276-16504 4/25/73
1076-16442 10/7/72	1295-16502 5/14/73
1095-16442 10/26/72	1313-16561 6/1/73
	1329-16443 6/17/73

[1] Comments on "significant environmental-geologic attributes" refer to the surficial deposits overlying the bedrock unless stated otherwise. Because of the small scale of the map and the fact that the mapping was done by interpreting ERTS-1 images without intensive ground surveys, these are generalized statements that suggest average characteristics for the map unit; they are appropriate for regional planning, but not for detailed planning and operations. For any specific operation, detailed field investigations will be required to determine the engineering properties of individual soil and geologic units.

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APPENDICES

EVALUATIVE MAPPING STUDIES

OF VARIOUS TEST AREAS

with contributions from

Dr. Jerry A. Lineback (Illinois State Geological Survey)
H. Kit Fuller (U.S. Geological Survey)
Richard K. Rinkenberger (U.S. Geological Survey)

A1.0 GEOMORPHOLOGIC-GEOLOGIC BACKGROUND FOR THE PROJECT REGION

Figure A1.1 shows the parts of the Great Plains-Midwest for which we prepared maps of analytic geomorphology by interpreting SL photos, as a means of evaluating the utility of these photos for such mapping. Figure A1.2 is a portion of Erwin Raisz' Map of the Landforms of the United States, showing the principal landforms in this region. Figure A1.3 designates (by Roman numerals) the four primary categories of landscape in this region:

> (I) In the northeast and north are relatively little-dissected drift plains formed by the last glaciation (Wisconsinan drift plains), which have a thick surficial cover mainly of glacial drift; (II) to the south are more-dissected drift plains of earlier glaciations (Illinoian and Kansan drift plains), generally a cover of wind-blown silt (loess) over glacial drift of variable thickness; (III) in the south and southeast are unglaciated, much-dissected upland plains where surficial deposits commonly are thin or absent; and (IV) in the west are the unglaciated central Great Plains, with highly variable thicknesses of loess, eolian sand, and alluvium.

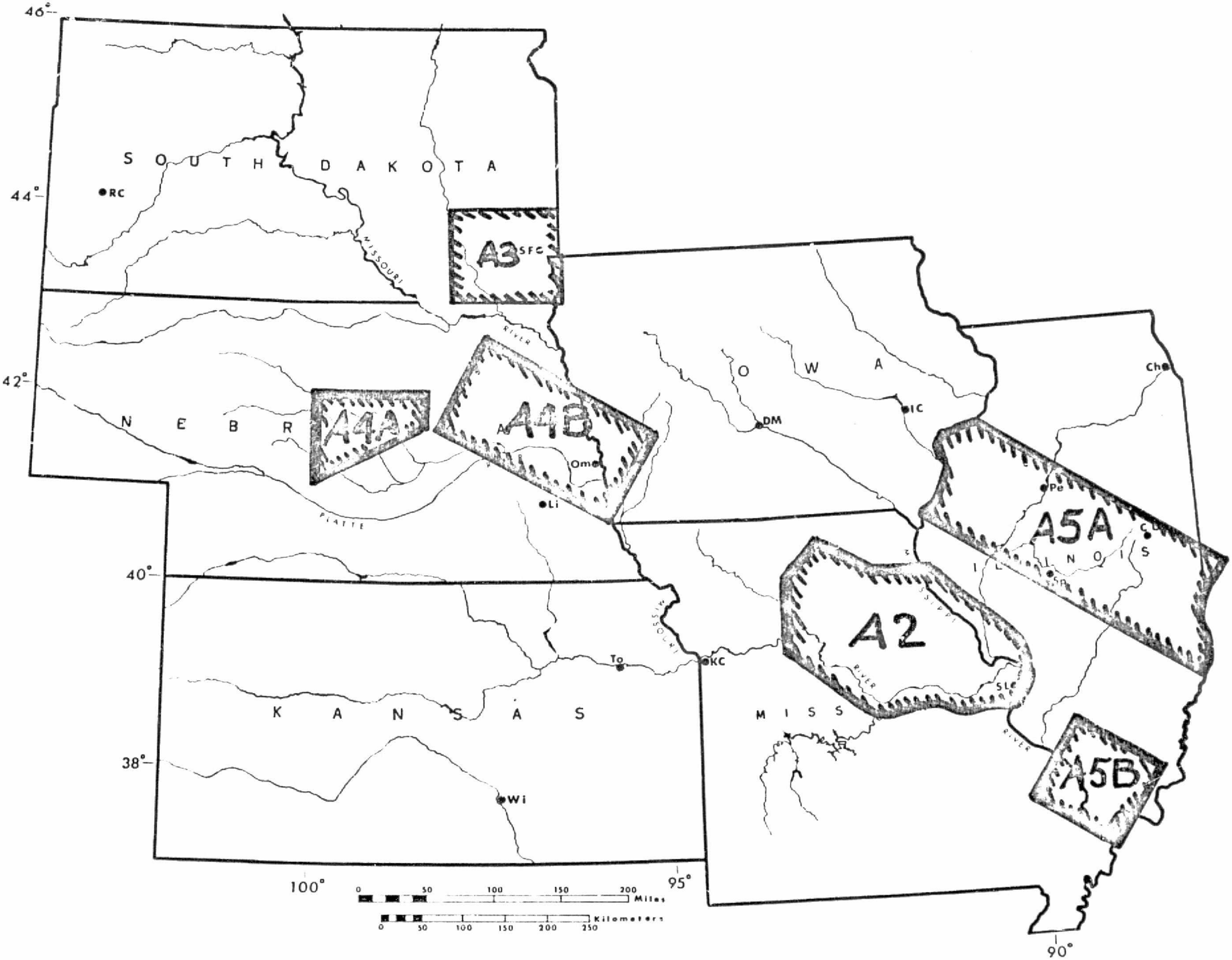
Throughout the region, the bedrock is nearly flat-lying and exposed only locally, mainly along deeply entrenched streams and in the southern and westernmost study areas. The climate ranges from continental moist (30 to 40 inches mean annual precipitation) in the east to continental steppe (commonly less than 20 inches m.a. precipitation) in the west.

Figure A1.1--NEAR HERE
A1.2--NEAR HERE
A1.3--NEAR HERE

The Wisconsinan drift plains (areas I on Fig. A1.3) are near the southern limit of the last glaciation and were formed by several lobes of the Laurentide continental ice sheet. The lobes reached their maximum southern limits between about 20,000±1,000 (Lake Michigan and Erie lobes) and 14,000 (Des Moines and James River lobes) radiocarbon years ago. These plains are underlain mainly by clayey till with little or no cover of wind-blown silt (loess). They consist in part of nearly level to gently undulating ground moraine (and locally, beds of former proglacial lakes), and in part of more or less concentric end moraines[6] that rise from less than 50 feet to more than 200 feet above the surrounding plain. Drainage is poorly integrated and stream dissection generally is very shallow; in the northernmost study areas lakes and ponds are common. In Illinois and in parts of other states the end moraines have been mapped in

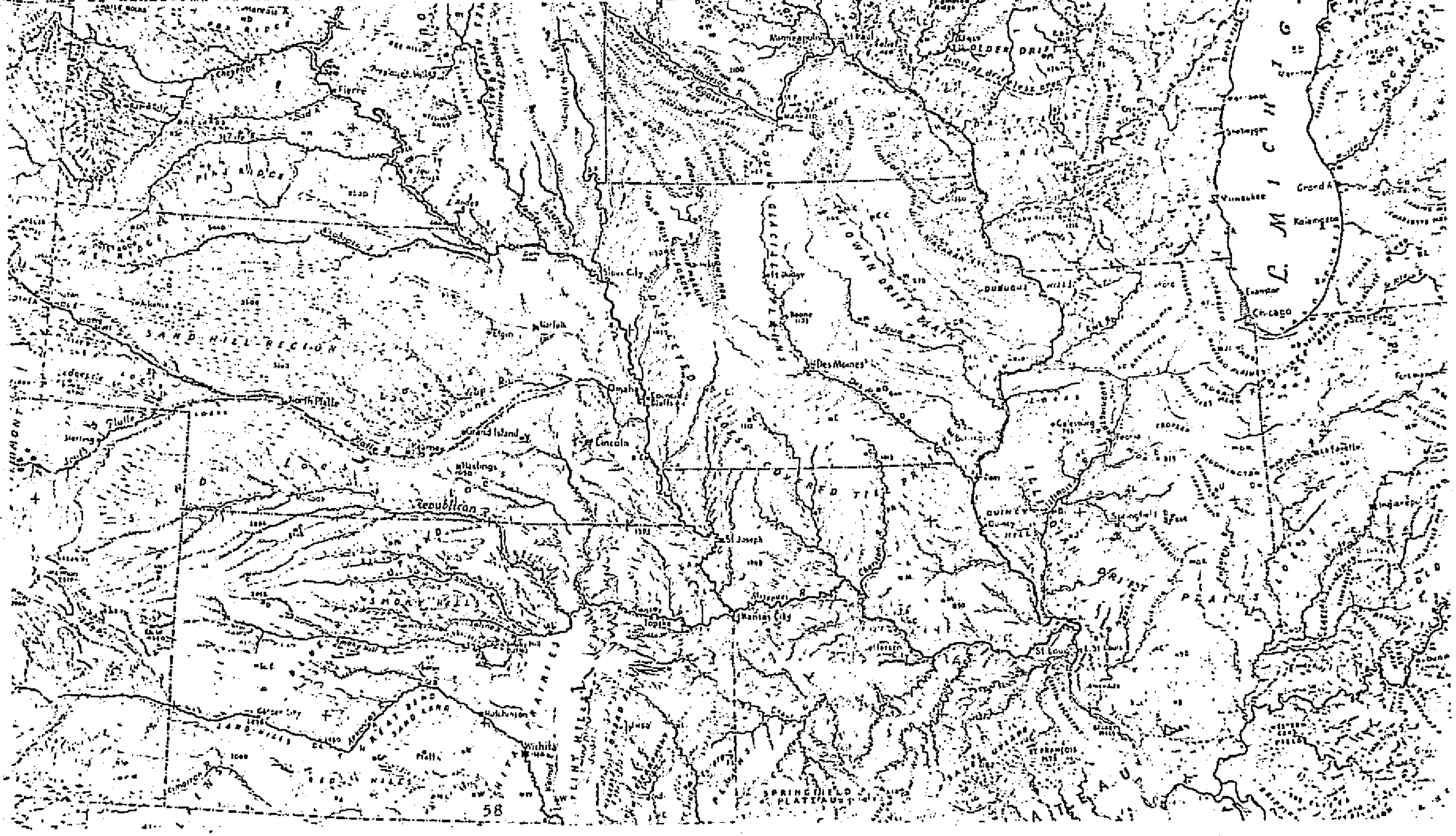
---

[6] The term "end moraine" is used in this report for any ridge-like landform of glacial drift. Some, probably most, are true end moraines (frontal moraines) deposited by melting of ice at the edge of a former ice sheet. They may record pulsating movements of the ice margin, including the maximum advance and younger readvances, or they may record recessional stillstands. Other "end moraines" may be glaciotectonic ridges formed by shearing (overthrusting) at the base of and within the ice sheet, generally as a result of compressive flow over a bedrock rise. Rarely, "end moraines" may be bedrock highs that are thinly mantled by drift. Considerable ground control (especially subsurface drillhole and/or geophysical data) generally is needed to establish the origin of an "end moraine."



A1.1. Map showing areas for which maps of analytic geomorphology were prepared. Symbols refer to sections in the Appendix in which they are discussed.

Figure A1.2. Great Plains-Midwest portion of Erwin Raisz' Map of Landforms of the United States.



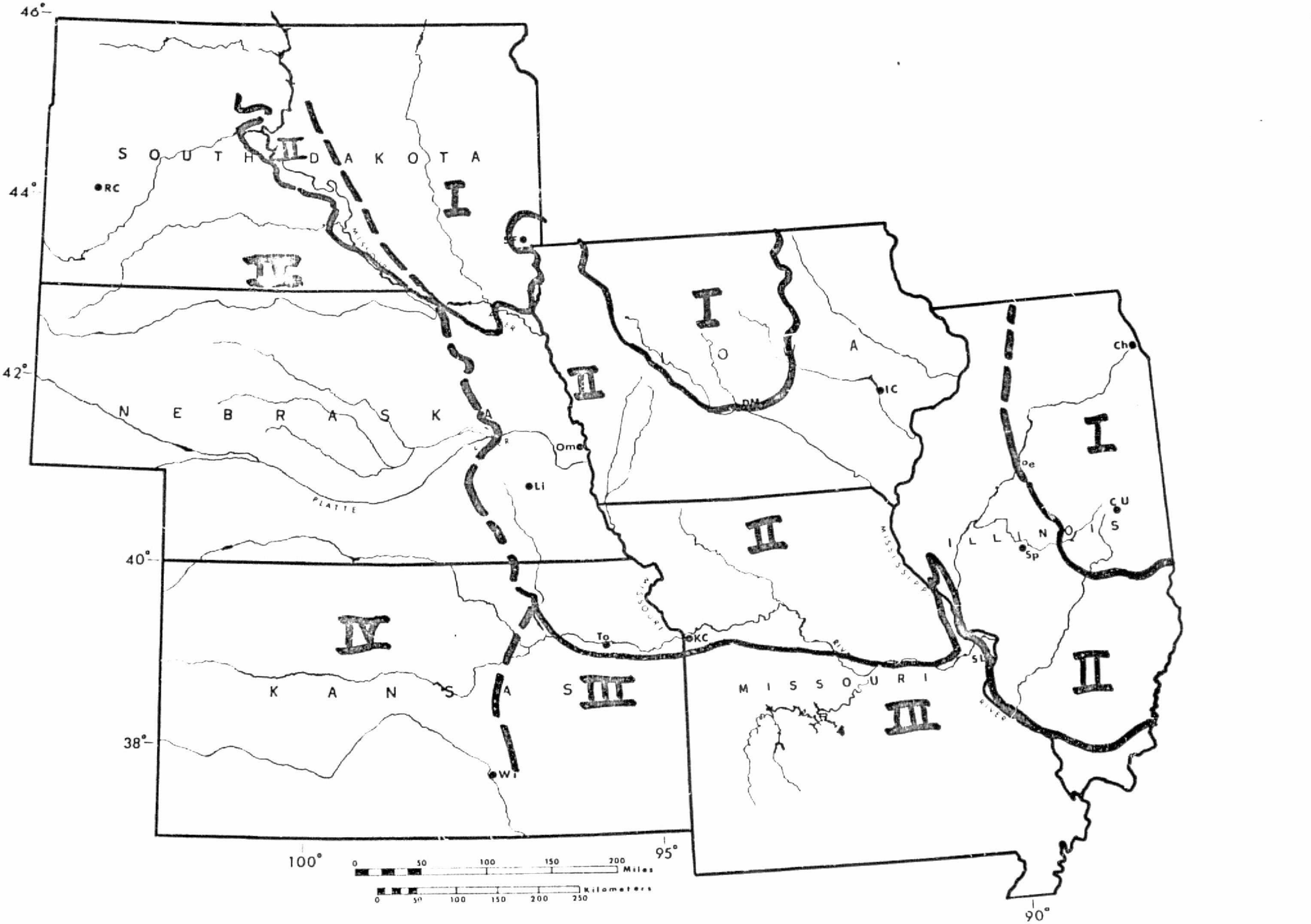


Figure A1.3. Map showing the four primary categories of landscape in the Great Plains-Midwest detail, but in many areas they are poorly known. Although they are relatively young and little eroded, their relief commonly is so low that they are difficult to distinguish on topographic maps and conventional airphotos. Thus, identification and mapping of the young end moraines was judged to be a moderately severe test of the applicability of the Skylab photos to geologic-terrain mapping in parts of the region characterized by generally low relief and by heavy vegetative cover during the growing season.

The older drift plains (area II on Fig. A1.3), of middle Pleistocene (Illinoian and Kansan) age, are so eroded and veneered by loess that little or none of the original glacial morphology is preserved. The major streams have trenched 30 m and, in places, 60 m, commonly through the entire surficial mantle and deeply into bedrock. The greatest relief is along the Mississippi and Missouri River and their main tributaries, where bluffs are common. Gently undulating uplands ("prairies") are common between the main streams.

The unglaciated parts of north-central Missouri and eastern Kansas (area III on Fig. A1.3) are moderately deeply dissected and have a thin, local surficial mantle on the uplands, mainly loess and colluvium. Here the lithologic and structural characteristics of the bedrock units dominate the geomorphology.

The unglaciated central Great Plains (area IV on Fig. A1.3) are gently eastward-sloping upland plains. Bedrock is exposed only locally, being generally concealed by a surficial mantle of variable thickness. The mantle is chiefly loessial (wind-blown silt) in the eastern Great Plains, but coarsens westward into large areas of eolian sand, such as the Sand Hills of Nebraska. Perennial streams are widely spaced, especially in the semiarid western part of the province. Stream dissection rarely exceeds 50 m along the main streams, and interstream upland plains commonly are wide and gently undulating to nearly level.

A2.0 NORTHEASTERN MISSOURI STUDY AREA
(Interpreted by H. Kit Fuller)

A2.1 General geomorphic background

This study area, in northeastern Missouri between the Mississippi and Missouri Rivers (Fig. A2.1), is an ancient drift plain, glaciated in Nebraskan, Kansan, and probably (in its eastern part) in Illinoian (early and middle Pleistocene) time. Its southern boundary is approximately the maximum limit reached by the ancient ice sheets. The stream dissection is mostly subsequent to glaciation and has resulted in a mature topography, with fairly broad valleys and rounded ridges in most places. Thick deposits of glacial drift are restricted to the less-eroded uplands well back from the principal streams. Loess commonly overlies the drift. It is highly variable in thickness, tending to thicken toward the Missouri River. Approaching the southern boundary of the area, the veneer of glacial drift and loess becomes highly variable in thickness and is absent in many places. Thus, a smaller proportion of this area is underlain by surficial deposits than in areas farther north.

This study area is comprised of five principal landscape areas, shown in Fig. A2.2:

Figure A2.1--NEAR HERE
A2.2--NEAR HERE

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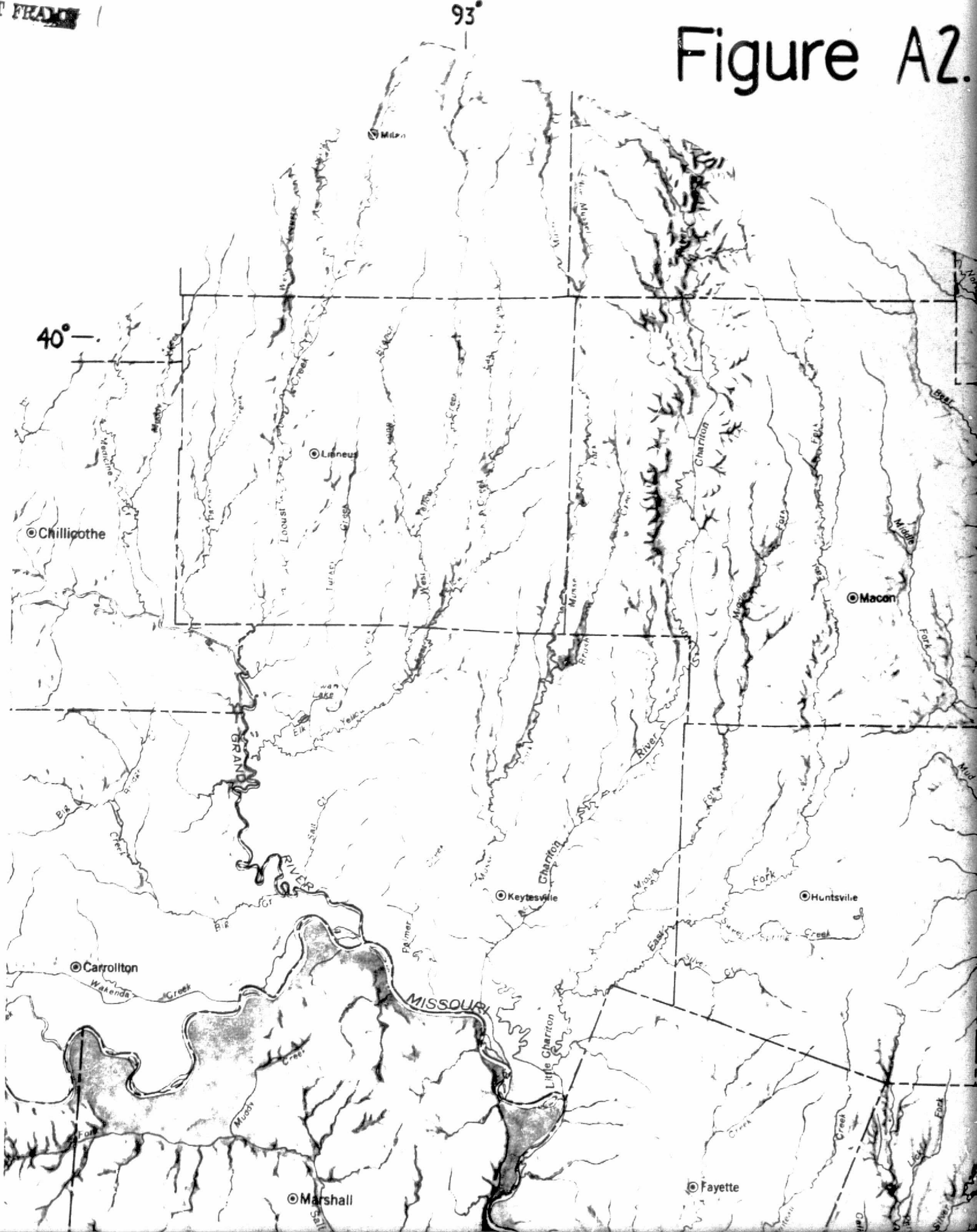
1. Mexico Plain. A flat to gently undulating upland plain, central to the study area, with widely spaced eastward-flowing streams; local relief generally is less than 15 m, but ranges to 60 m along the deeper valleys near its eastern limit. Nearly continuous surficial mantle over bedrock, consisting of 2/3 to 1 1/2 m of pale yellow-gray loess over glacial drift (middle Pleistocene) averaging about 15 m in thickness. Extensively formed and characterized by very regular rectangular field patterns, very few woodlands on steeper slopes. Poorly drained acid soils limit farming to mostly wheat, corn, and soybeans.

2. Dissected uplands northeast of the Mexico Plain. Highly dissected upland plain with fairly accordant ridge tops, some to few narrow gently sloping interfluves, steep valley sides; 30-90 m local relief. Discontinuous surficial mantle of loess over glacial drift, chiefly on the ridge crests (bedrock commonly is exposed in the deeper valleys); loessic deposits thicken and glacial drift thins toward the Mississippi River, as dissection increases and slopes steepen. Small scattered areas of karstic (sinkhole) topography. Mostly woodlands and pastures, on slopes too steep to be farmed; some croplands on gently sloping interfluves and narrow alluvial lowlands. Fields are commonly small and irregular.

3. Highly dissected uplands south of the Mexico Plain. Between the Missouri River and the Mexico Plain is a closely dissected area with local relief commonly >60 m, increasing to locally ca. 90 m along the Missouri River. Boundary with Mexico Plain is abrupt. Much exposed bedrock; local loessial cover, thickest (commonly >6 m) on bluffs near Missouri River;

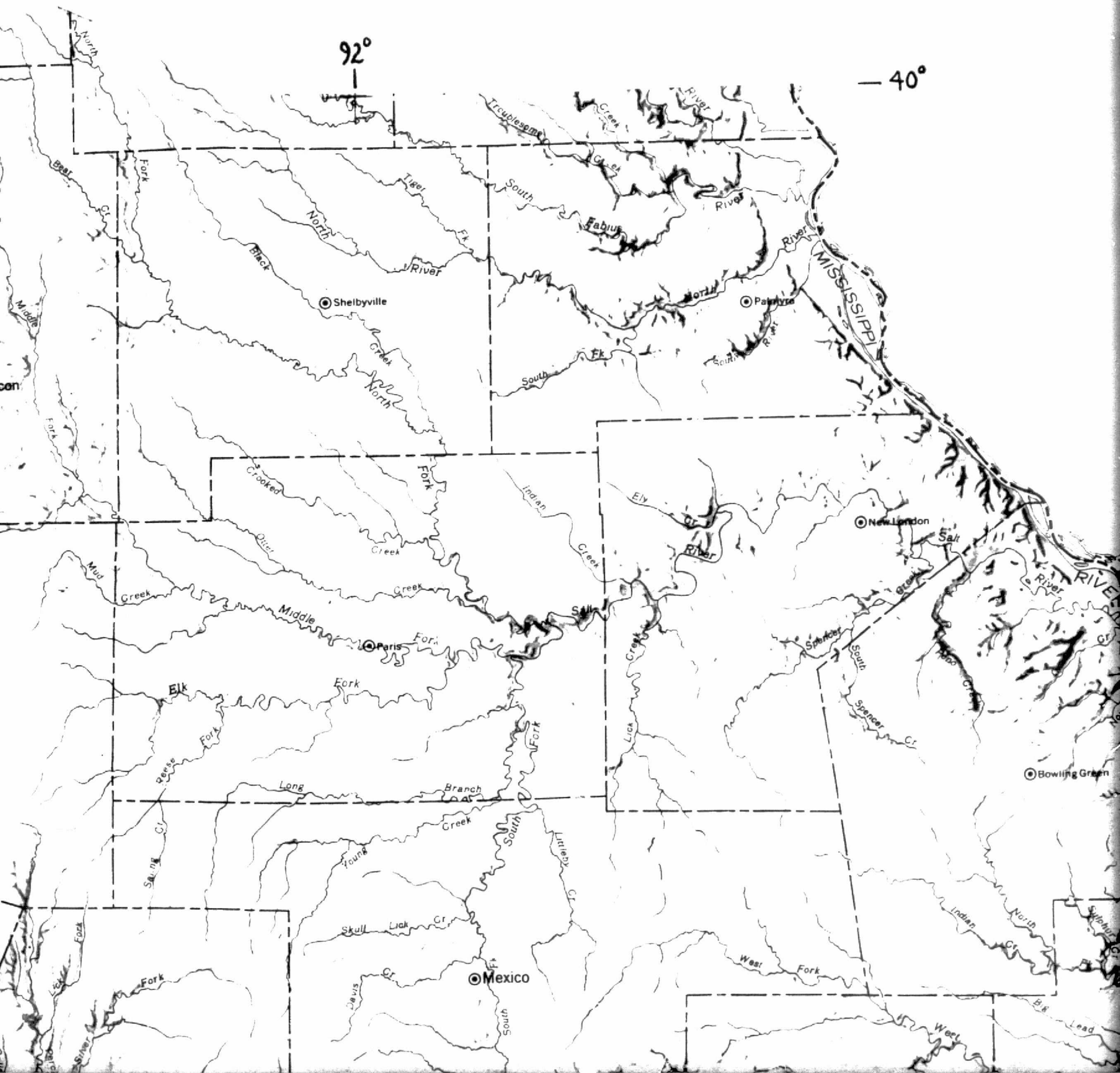
OLDOUT FRAME 1

Figure A2.



FOLDOUT FRAME 2

A2.1. N E MISSOURI STUDY



FOLDOUT FRAME 3

Y AREA

91°

FOLDOUT FRAME 4

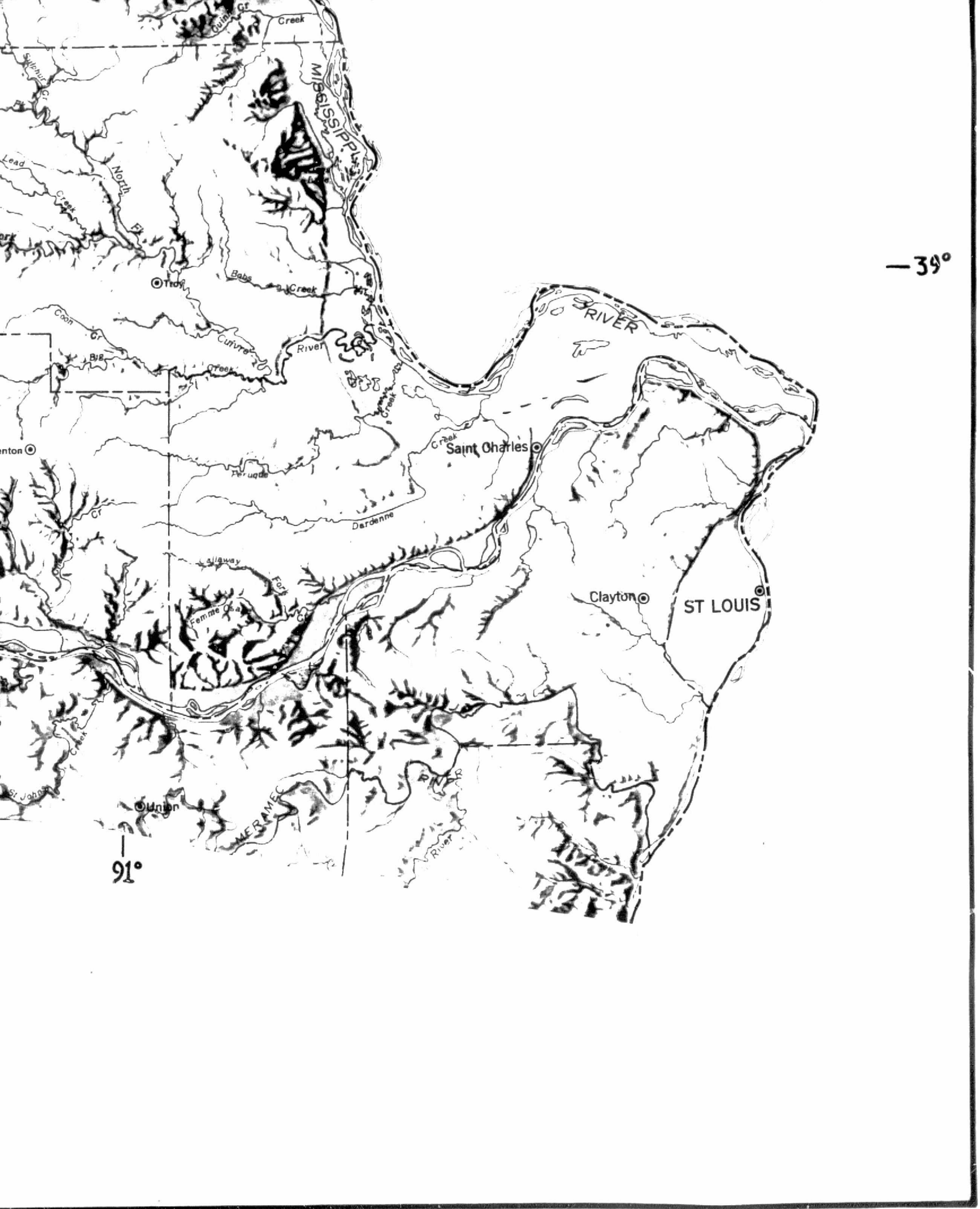
Scale 1:500 000

1 inch equals approximately 8 miles

10 0 10 20 30 40 Miles

10 0 10 20 30 40

FOLDOUT FRAME 5



Creek
MISSISSIPPI
Sulphur Cr.
Lead
Creek
North
Fk.
Troy
Bobs
Creek
RIVER
Coon
Cr.
Big
Cuivre
River
Creek
Creek
Saint Charles
Peruque
Dardenne
Cr.
Callaway
Fork
Femme Osage
Cr.
Clayton
ST LOUIS
St Johns
Creek
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MERAMEC
RIVER
River
91°
39°

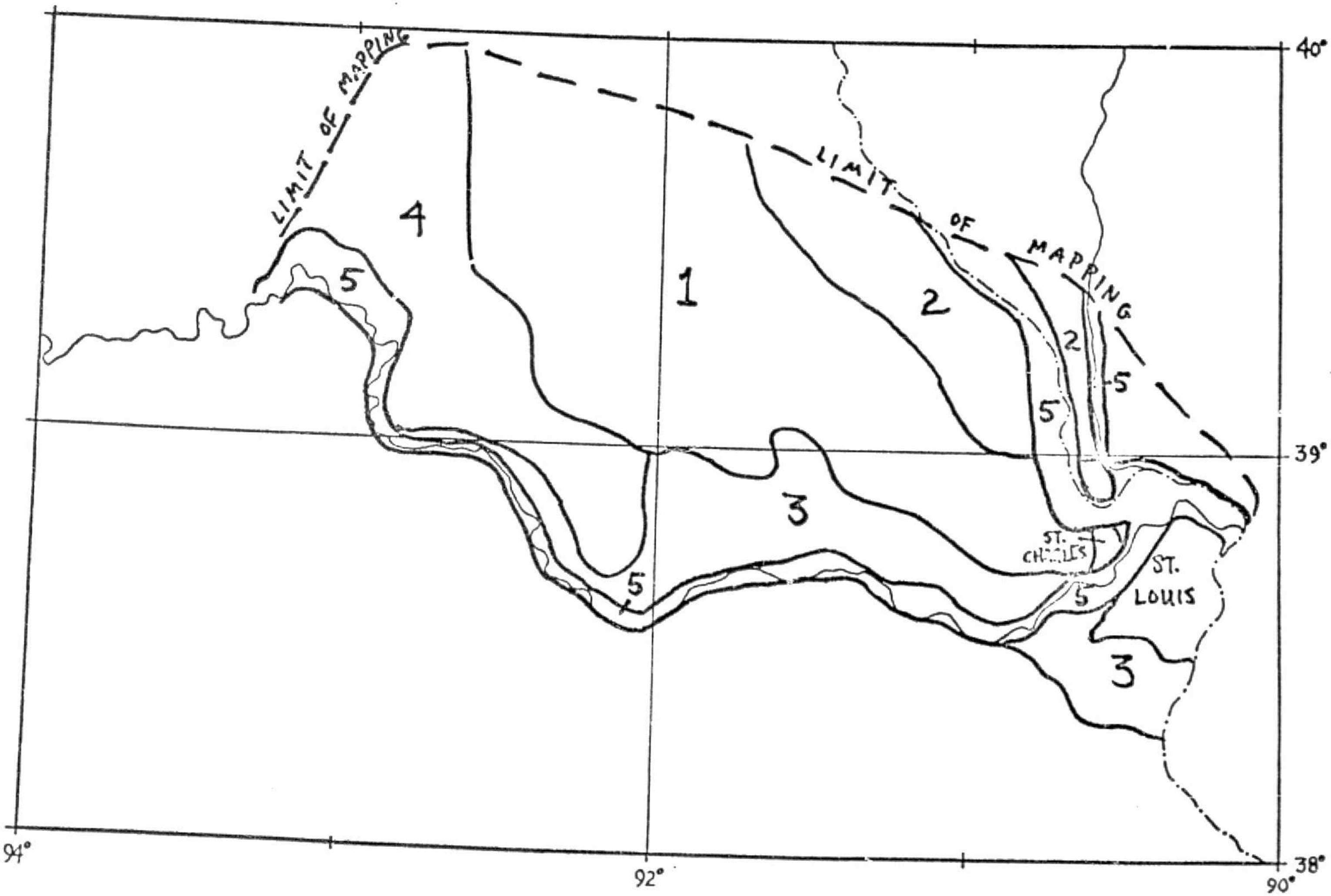


Figure A2.2 Chief landscape units in NE Missouri study area.

little or no glacial drift. Slopes generally steep, few gently sloping interfluves. Mostly woodlands and pastures, some orchards. North part of western half of unit is underlain by commercially strippable coal. A few small areas of karst topography.

4. Moderately dissected hillland west of the Mexico Plain. Rolling hills with moderate slopes, drained to south by Chariton River; local relief generally <30 m. Cover of loess 2/3 to 3 m thick over till and other unconsolidated materials 22-30 m thick. About 60% cropland, on moderately to sloping uplands and narrow valley lowlands; remainder (slopes too steep to farm) is woodland, pasture, and strip mines. Fields generally large and rectangular. Much of area is underlain by strippable coal or already stripped of coal; those stripped are in various stages of revegetation.

5. Alluvial lowlands along Mississippi, Missouri, and Illinois Rivers. Essentially flat, moderately well drained to poorly drained alluvial and lacustrine clay, silt, sand, and gravel with generally high water table. Mostly 5 to 8 km wide (extreme width 24 km). Depth to bedrock more than 30 m. High risk of flooding limits unprotected areas to woodland and pasture; grain farming behind levees. Effects of March-June 1973 flooding are very evident--flood scars, standing water, and water of Missouri River still very muddy.

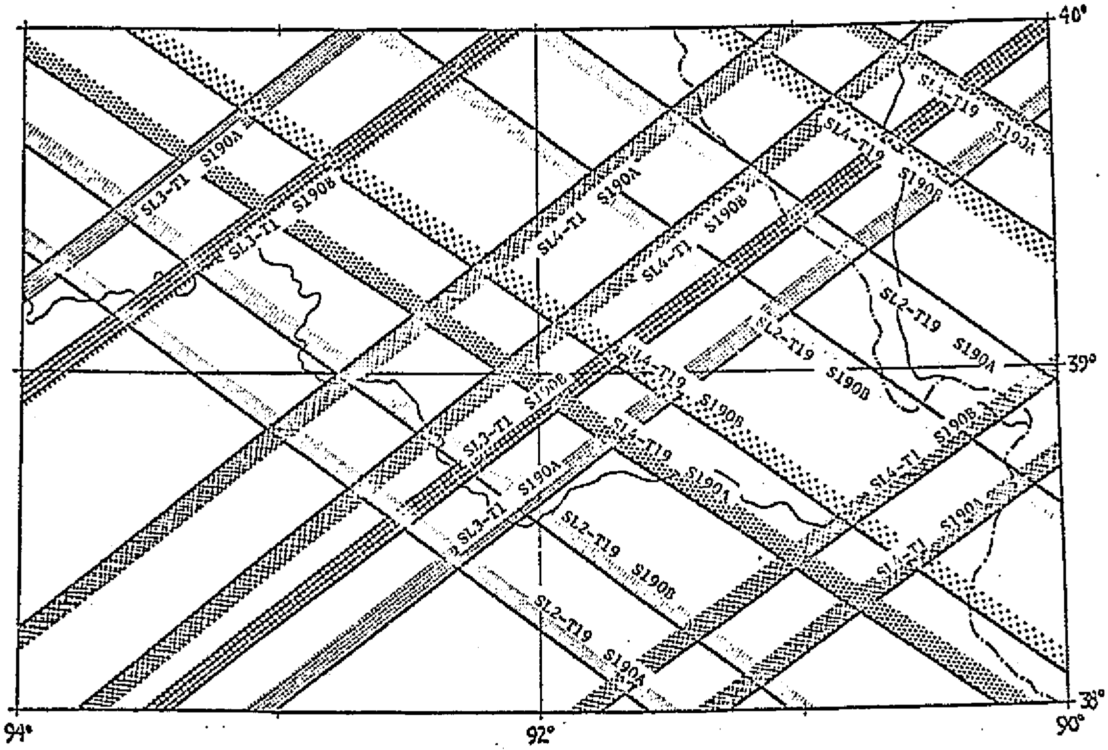
Figure A2.3(B) shows the coverage of this study area by published geologic maps. (The references shown are listed in the "References cited" section of this report.)

Figure A2.3--NEAR HERE

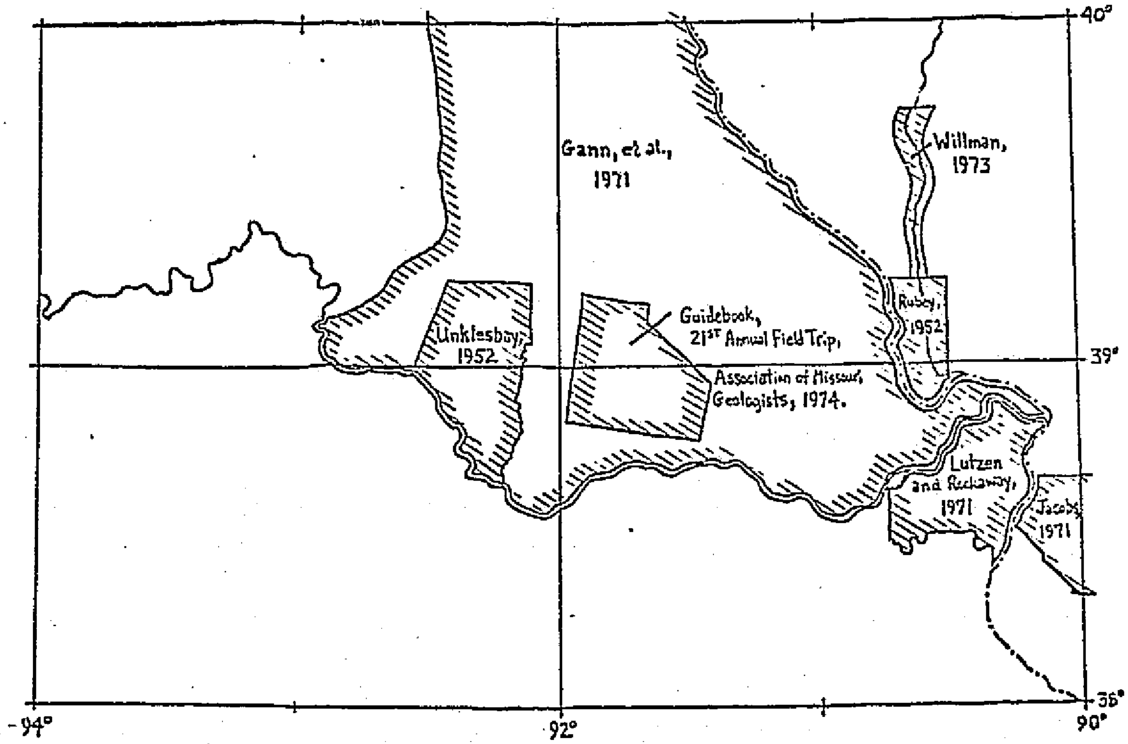
A.2 Evaluation of Skylab photo coverage of the area

Figure A2.3(A) shows the coverage of this study area by SL photos. Following is a detailed evaluation of the quality and utility of these photos.

Mission/ Track	Date Photographed	Most Useful Bands (Roll and Frame Nos.), and why:
SL2 Pass 6 Track 19	6/10/73	S190B color (roll 81, frames 185-188) are most useful of all SL photos of this area; cloud free, >60% stereo overlap, very good color balance, and very good distinguishable detail. S190A color (roll 10, frames 142-144) unenlarged transparencies are fairly sharp, but enlargements are very fuzzy; good color, but details not as recognizable as on S190B. S190A red (roll 11, frames 135-137) and CIR (roll 9, frames 142-144) are somewhat less useful; red enlargements too contrasty but show much cultural detail; CIR emphasizes vegetation, but lacks resolution necessary for distinguishing finer detail.



A. Skylab photo coverage.



B. Geologic map coverage.

Figure A2.3. Coverage of NE Missouri study area by

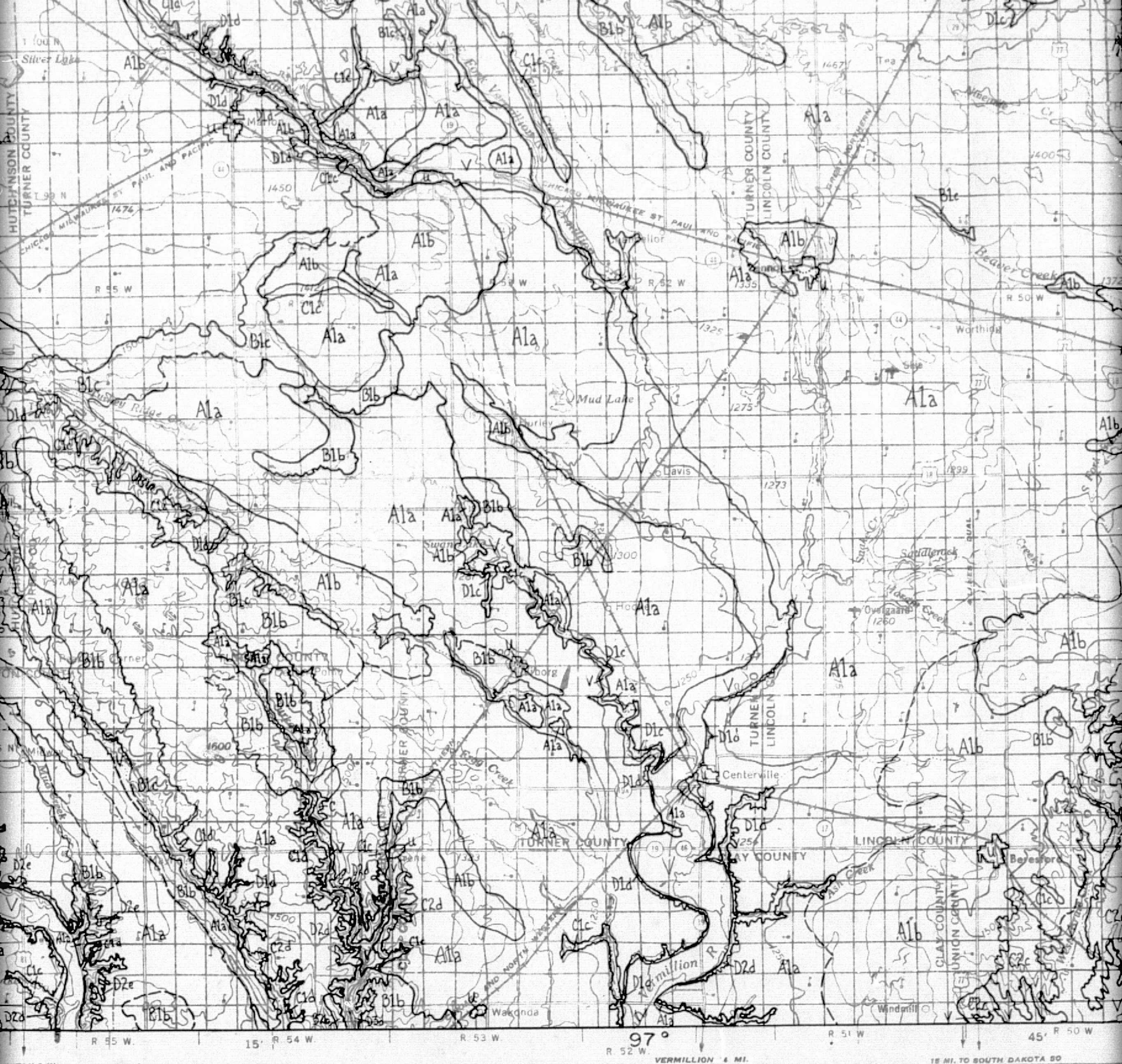
Skylab photos and geologic maps.

Figure A2.5a. Analytic geomorphology of part of northeastern Missouri. Overlay to 2X enlargement of SL2 Pass 6 S190B color photo 81-184.

Mission/ Track	Date Photographed	Most Useful Bands (Roll and Frame Nos.), and why:
SL3 Pass 48 Track 1	9/10/73	Only about 15% overlap in all bands, and >50% obscured by scattered clouds and cloud shadows. S190B color (roll 88, frames 216-218) best for "seeing around" clouds; good detail visible and land-use noise minimized by uniformity of vegetative cover. Woodlands in strip-mined areas, on steeper slopes, and along upper reaches of streams contrast well with cropland vegetation (this contrast is obscured in SL2 photos by land-use noise). S190A color (roll 46, frames 194-195) and CIR (roll 45, frames 194-195) both show fairly well the vegetation differences mentioned above; color has better rendition of detail than CIR.
SL4 Pass 82 Track 1		S190B color (roll 92, frames 114-117) are most useful of this track; although >50% snow-covered, they are helpful for checking local relief and density of dissection; some areas of karst topography can be seen. S190A color (roll 64, frames 289-291) and CIR (roll 63, frames 289-291) are the only other useful bands, although both are so overexposed that only the larger terrain features can be seen; color shows well the karst area north of St. Louis.
SL4 Pass 54 Track 19	11/30/73	S190B color (roll 90, frames 23-25) is only useful roll of this track. Much is unusable because of clouds and haze, but remainder has excellent sharpness of detail, color balance, and exposure. Land-use pattern is not as distracting as in spring, but variations are more evident than in summer; very good distinguishability of culture and land-surface detail. S190A coverage is much more obscured by clouds, usually with under or overexposure; enlargements generally are poorly processed and out of focus.

A2.3 Interpretive procedure and results

The interpretive mapping was done on transparent overlays to enlarged transparencies (2 X and 4 X) of the better-quality SL photos of the area (SL2 Pass 6 (Track 19) S190B and S190A color, CIR, B/W red, and B/W farther IR bands). The enlargements were first viewed singly on a light table without magnification, and then using 7 X and 20 X comparators. After location of major features and urban areas, and cursory examination of 1:250,000 topographic maps of the area, the same frames were studied stereoscopically, using an Old Delft scanning stereoscope, under 1.5 X and 4.5 X magnification. Most delineation of landscape-unit boundaries was done while examining frames in stereo, referring to topographic maps (1:24,000, 1:62,500, and 1:250,000 scales), geologic maps and reports, and U-2 and WB57 airphotos for ground control.



Scale 1:250,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilometers

5 0 5 10 15 Nautical Miles

3 LANES | 4 LANES
marker
3 LANES | 4 LANES
route markers
s: School; Church; Other
control point
tion in feet
swamp
nt or dry stream

CONTOUR INTERVAL 50 FEET
WITH SUPPLEMENTARY CONTOURS AT 25 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION

1965 MAGNETIC DECLINATION FROM TRUE NORTH FOR THIS SHEET VARIES FROM 9½° (170 MILS) EASTERLY FOR THE CENTER OF THE WEST EDGE TO 8° (140 MILS) EASTERLY FOR THE CENTER OF THE EAST EDGE.

FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR WASHINGTON, D.C. 20242

FOLDOUT FRAME 6

Figure A2.4a illustrates a typical overlay map for a 4 X enlargement of a S190A color-infrared transparency; and Figure A2.5a shows an overlay map for a 2 X enlargement of a S190B color transparency. Figures A2.4b and A2.5b are strip maps prepared as overlays to several S190A or S190B frames covering the entire study area.

Figure A2.4a--NEAR HERE
A2.4b--NEAR HERE
A2.5a--NEAR HERE
A2.5b--NEAR HERE

When drawing boundaries between major land-surface types a hierarchy of distinguishability emerged. First, major river lowlands were differentiated; second, the Mexico Plain was delimited from the more strongly dissected areas surrounding it; then finer distinctions were made within the major units based on variations in land-use patterns, differing soil-moisture conditions, differences in vegetal color and reflection, and information gleaned from examination of various kinds of ground control and Skylab photos from other flights.

A2.4 General evaluation

The most useful photos were the 2 X enlargements of SL2 Pass 6 (Track 19) S190B color, and the 4 X enlargements of S190A color, CIR, and B/W red. The SL4 photos would have been very useful had they been properly exposed and the enlargements not out of focus. Also, the SL3 Pass 48 (Track 1) photographs would have been more useful with 60 percent overlap, because stereoviewing would have lessened the obscuring effect of the scattered clouds, permitting viewing the ground "through" them. Although stereoviewing did yield more information on the land-surface features than viewing singly, all the SL photos provide too little stereorelief to permit good estimates of the local relief. In other words, greater exaggeration of relief would have been very helpful, because relief is a major factor in geomorphic mapping. The amount of local relief almost always was underestimated (both with the Old Delft stereoscope and with the Kern plotter), and had to be corrected by checking with 7 1/2-minute or 15-minute topographic maps. At best, in the sharpest photos viewed under 4.5 to 5 X magnification, relief could be estimated within about 10 m; usually, however, without familiarity with local ground conditions, local relief could not be estimated more closely than about 30 m. Steep slopes are recognizable partly because of land-use changes, but their relief usually was underestimated; on the other hand, gentler slopes were seldom noticeable, especially if no significant change in land use occurs at the breaks in slope.

A major problem with mapping on the SL2 Pass 6 (Track 19) photos is their great amount of land-use "noise"--information mainly from farming practices that distracts from or obscures information on geomorphology. The strong contrast of newly-plowed fields with adjacent fallow or vegetated fields distracts from the subtle tonal differences that indicate changes in topography, soils, or natural vegetation. In many cases, the boundaries of landscape units were mapped incorrectly on the SL2 Pass 6 (Track 19) photos, but later corrected after checking photos from later missions. Also the distribution of woodlands

Figure A2.4a [illegible] 4X enlargement [illegible]

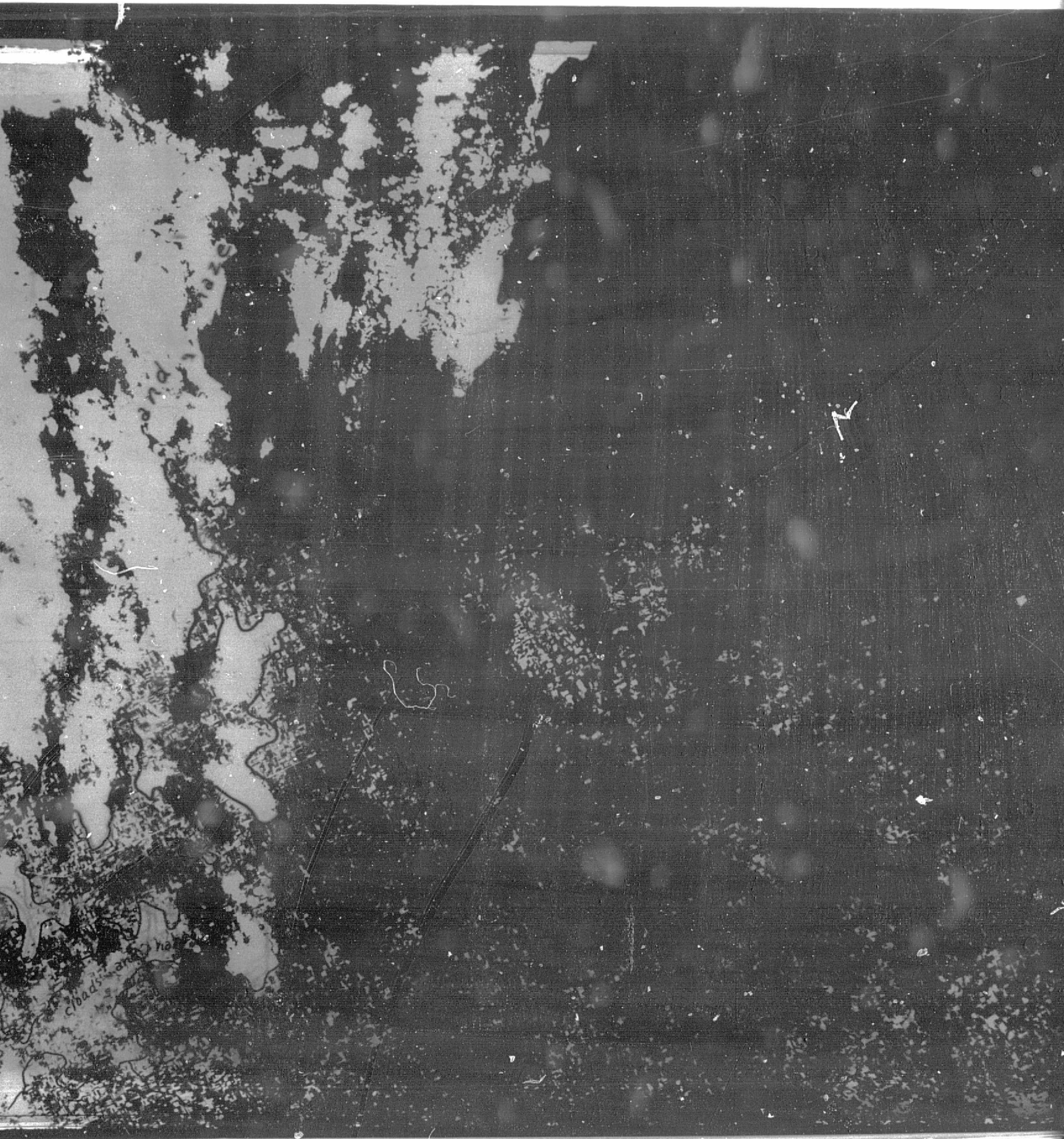


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Figure A2.4

MAP UNITS	ATTRIBUTES IDENTIFIABLE ON SKYLAB PHOTOGRAPHS							SURFICIAL-GEOLOGIC DEPOSITS			
	LANDFORM CHARACTERISTICS					SOIL CHARACTERISTICS					
			Stream dissection								
	Land-surface form symbol(s)	Local relief (meters)	Density	Pattern	Interfluves	Surface Color	Soil Drainage		Topographic limitations	Shallow ground water availability	Gr... availa... qu...
1	Ala	<10	—	—	—	Light	Good-poor	Alluvial clay, silt, sand; gravel locally	3	3	2,
1w	Ala	<10	—	—	—	Dark	Very poor	Do.	3	3	3
1d	Ala	<10	—	—	—	Light	Poor to good	Do.	3	3	3
21	Ala, Alb,	<20	Medium	Dendritic, locally arcuate, angular, or parallel-dendritic	Flat; <30 m above present streams	Light	Poor-very good	Late Wisconsinan loess, underlain by glacial till	3	1, 2	1,
2c	Do.	<20	Medium	Dendritic	Do.	Dark	Very poor-fair	Mainly older loess underlain by till; very clayey	3	1, 2	1,
31	Blb, Blc, B2c	<30	Medium	Pinnate, parallel	Rounded to flat, accordant summits	Light	Fair-very good	Late Wisconsinan loess in places underlain by till	2, 3	2	1,
3c	Do.	<30		Pinnate	Do.	Dark	Very poor-fair	Possibly older loess underlain by clayey till or residuum	2, 3	2	1,
4c	Clb, Clc, C2c, Dlc	20-45	Medium	Dendritic	Flat to rounded	Light-medium	Fair	Discontinuous surficial cover of loess, in places over thin glacial drift	2	2	1,
4d	Cld, C2d, D2c, D2d	30-60	Fairly high	Sub-parallel	Rounded	Light	Fair to very good	Discontinuous late Wisconsinan loess over earlier loess, local till, and colluvium	1, 2	2	
5d	C3d, D3d	45-60	Fairly high	Deranged	Narrow with steeply sloping sides	Medium-light	Good-very good	Thick late Wisconsinan loess	1, 2	2	
5e	Do.	Do.	Do.	Sub-parallel	Do.	Do.	Do.	Do.	1	2	
6b	D3e, D4e	>60	High	Semi-radial	Do.		Very good	Much late Wisconsinan loess, 1-8 m thick, underlain by colluvium	1, 2	2	
7a	Blc, Clc	<30	—	—	Some flat, mostly rounded	Ranges: light-dark	Fair	Colluvium from glacial tills and loess	1, 2	2	
7b	C2c, C2d, C3c	30-60	—	—	Mostly steeply sloping, rounded	Do.	Good	Do.	1	2	1
7c	C3c, C3d	>60	—	—	Very steeply sloping, rounded	Do.	Very good	Do.	1	1, 2	1
K	Blc, Clc, B2c, C2c	15-45	Very low	Deranged	Wide and rolling	Dark	Poor-very good	Loessial soils	2, 3	1, 2	2

Special Symbols

U = Urbanized area
M = Strip mine (coal), clay pit, quarry
W = Lake, pond, major river

FOLDOUT FRAME 2

...ures A2.4a, A2.4b, A2.5a, and A2.5b. Explanation for analytic-geomorphology maps of the NE Missouri study area.

ENVIRONMENTAL-GEOMORPHIC/GEOLOGIC LIMITATIONS (Rating system: 1=severe limitations; 2=moderate limitations; 3=few limitations.)

...d ...lity	Gravel availability/ quality	Rock availability/ quality	Construction				Drainage		Erodibility	Waste Disposal			Special pro... or attrib...
			Slope stability	Foundations	Ease of excavation	Roads	Surface	Soil (internal)		Sanitary landfills	Sewage lagoons	Septic tanks	
	2, 3	1	1, 2	1-3	3	3	1, 2	1-3	1-3	1-3	1-3	1-3	Commonly subject ... near streams; hig... table in many pla...
	3	1	1	1	3	2, 3	1	1	2, 3	1	1	1	Very poorly drain... are areas behind ... principal streams... flood waters from... streams tend to b...
	3	1	1, 2	1	3	3	1	1	1-3	1	1	1	Extremely flood p... generally well dr...
	1, 2	1	2, 3	2, 3	3	3	3	2, 3	2	2	2	2	
	1, 2	1	2, 3	1, 2	3	3	2, 3	1, 2	2	3	2, 3	1, 2	
	1, 2	1	2, 3	2, 3	3	2	2, 3	2, 3	2	2, 3	2, 3	2	
	1, 2	1	2, 3	2	3	2	2	1, 2	2	3	2, 3	1, 2	
	1, 2	2	1-3	2	3	2	3	2, 3	1, 2	2	2	2	
	2	2	1, 2	2	3	2, 3	3	2	1, 2	2	3	3	
	1, 2	2, 3	2	2	3	1, 2	3	2	1, 2	2	2	2	
	1, 2	2, 3	2	2	3	1, 2	3	2	1	2	2	2	
	1, 2	2, 3	2	2	3	1, 2	3	2, 3	1, 2	1	1	1	Danger of collap... in underlying li... bedrock.
	2	2, 3	1, 2	2	1	2	3	2, 3	1, 2	2	1, 2	1, 2	
	1, 2	3	1-3	2	1, 2	2	3	2, 3	1, 2	2	1, 2	1, 2	
	1, 2	3	1-3	1, 2	1, 2	2	3	2, 3	1	2	1, 2	1, 2	
	2, 3	2, 3	1, 2	1, 2	2, 3	1, 2	1-3	3	3	1	1	1	Danger of ground... contamination; a... collapse of lime...

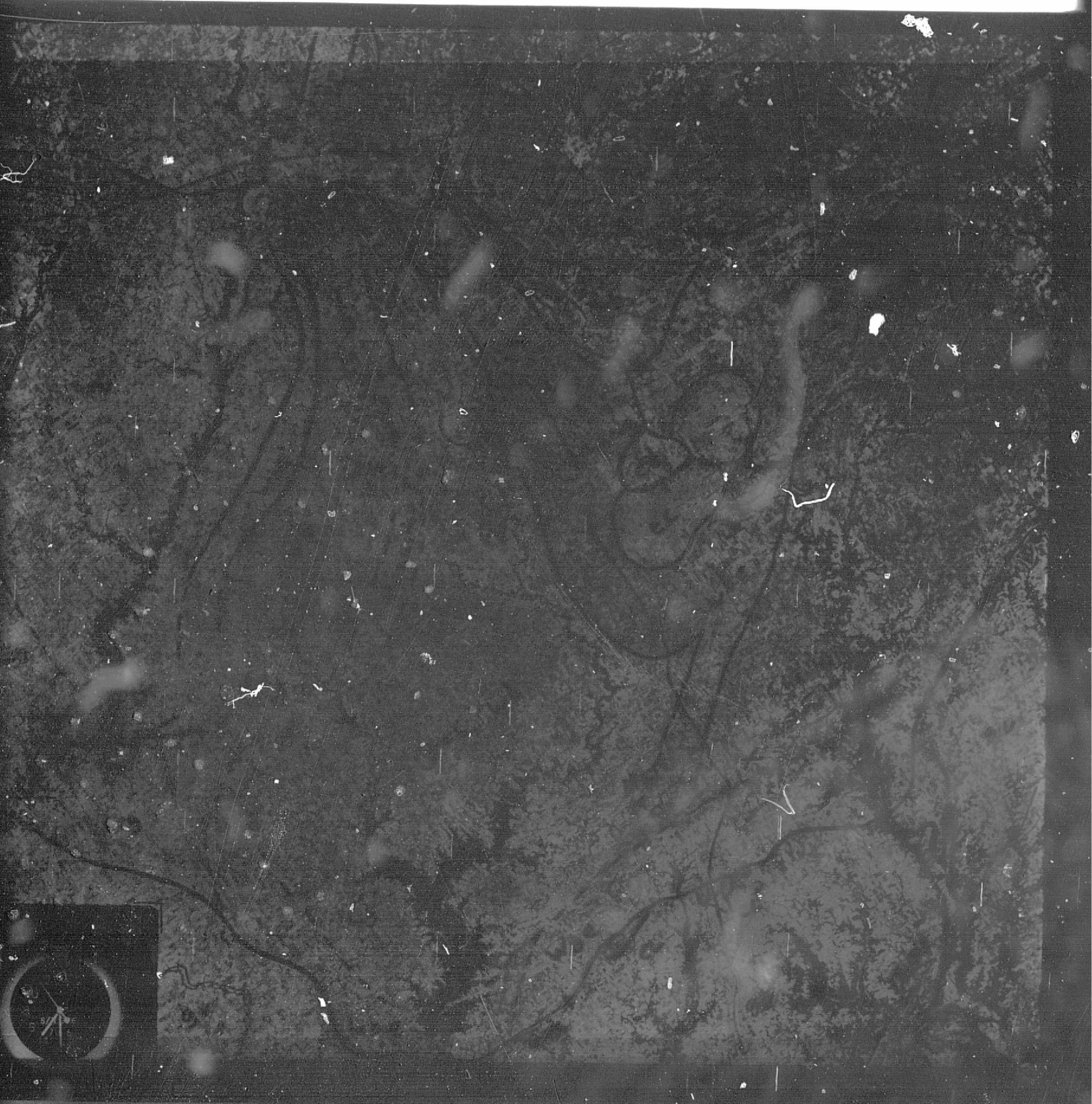
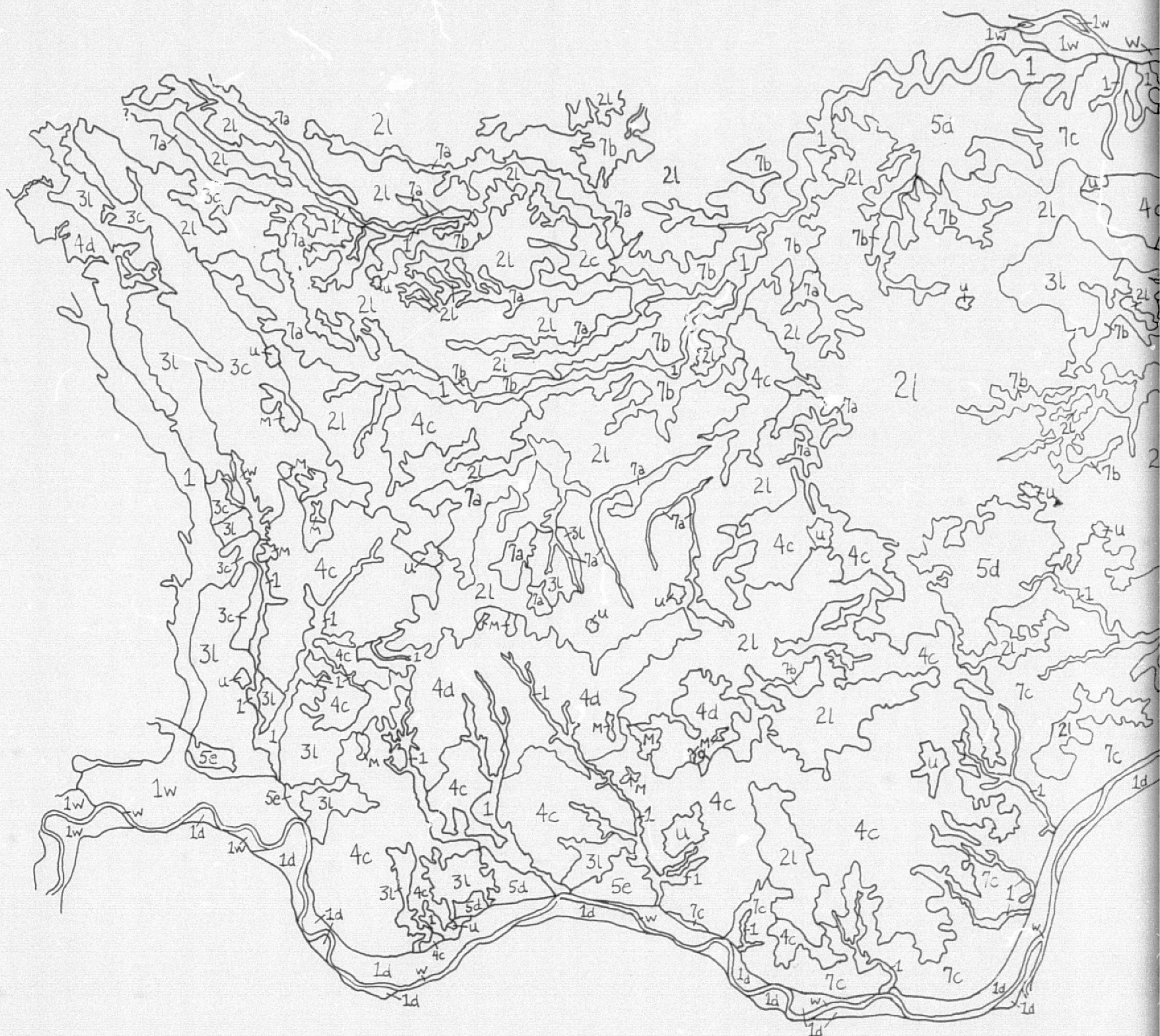


Figure A5.4 Conventional surficial-geologic map of part of the area shown in Fig. 5.1. Overlay to 2X enlargement of SL2 Pass 7 S190B color photo 81-336.

FOLDOUT FRA[illegible]

:tudy area.

a limitations; 3=few limitations.)					
	Waste Disposal				
:odibility	Sanitary landfills	Sewage lagoons	Septic tanks	Special problems or attributes	Remarks
1-3	1-3	1-3	1-3	Commonly subject to flooding near streams; high water table in many places.	Valley lowlands: floodplains of Holocene age and lower stream terraces.
2, 3	1	1	1	Very poorly drained; these are areas behind levees along principal streams, where flood waters from tributary streams tend to be impounded.	River bottomlands still or recently innundated by spring 1973 floods.
1-3	1	1	1	Extremely flood prone; soils generally well drained.	Raw alluvium deposited on river bottomlands by spring 1973 floods.
2	2	2	2		Gently undulating upland plains underlain by late Wisconsinan loess over middle Pleistocene glacial drift.
2	3	2, 3	1, 2		Like above but much older loess, which is weathered and clayey.
2	2, 3	2, 3	2		Gently rolling hills, generally covered by loess over middle Pleistocene glacial drift.
2	3	2, 3	1, 2		Do., but loess probably is weathered and more clayey. Many coal strip mines.
1, 2	2	2	2		Hilly upland with generally <30 m local relief. Bedrock locally exposed in valleys. Many coal strip mines.
1, 2	2	3	3		Like above but greater relief, more steep slopes and woodlands. Many coal strip mines.
1, 2	2	2	2		Highly and closely dissected upland, many steep valley slopes which are wooded.
1	2	2	2		Like above but mostly steep valley slopes (wooded).
1, 2	1	1	1	Danger of collapse of caverns in underlying limestone bedrock.	Deeply dissected upland over limestone bedrock (karstic areas not identifiable on SL photos); many limestone quarries; mostly wooded.
1, 2	2	1, 2	1, 2		Steeply sloping valley sides, local relief <30 m. Much exposed bedrock. Includes valley lowlands too narrow to be mapped.
1, 2	2	1, 2	1, 2		Steep valley sides and bluffs, local relief 30-60 m. Much exposed bedrock.
1	2	1, 2	1, 2		Very steep, closely dissected valley sides and bluffs, local relief >60 m. Many small karst areas northeast of Mexico Plain.
3	1	1	1	Danger of ground-water contamination; also of collapse of limestone caverns.	Development of such an area endangered by possible future sinkhole development, severe waste disposal limitations, and local slope instability.



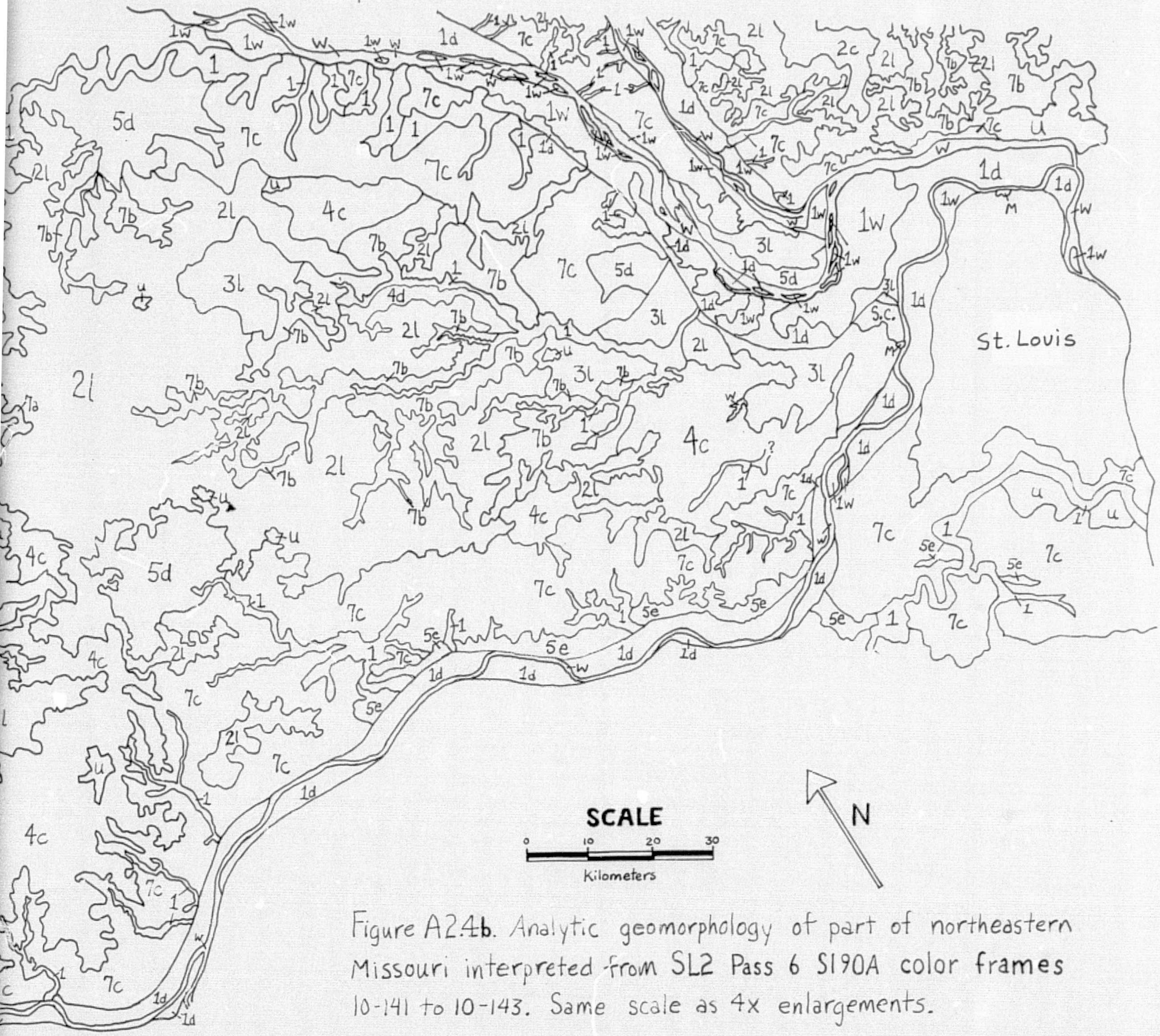


Figure A2.4b. Analytic geomorphology of part of northeastern Missouri interpreted from SL2 Pass 6 S190A color frames 10-141 to 10-143. Same scale as 4x enlargements.

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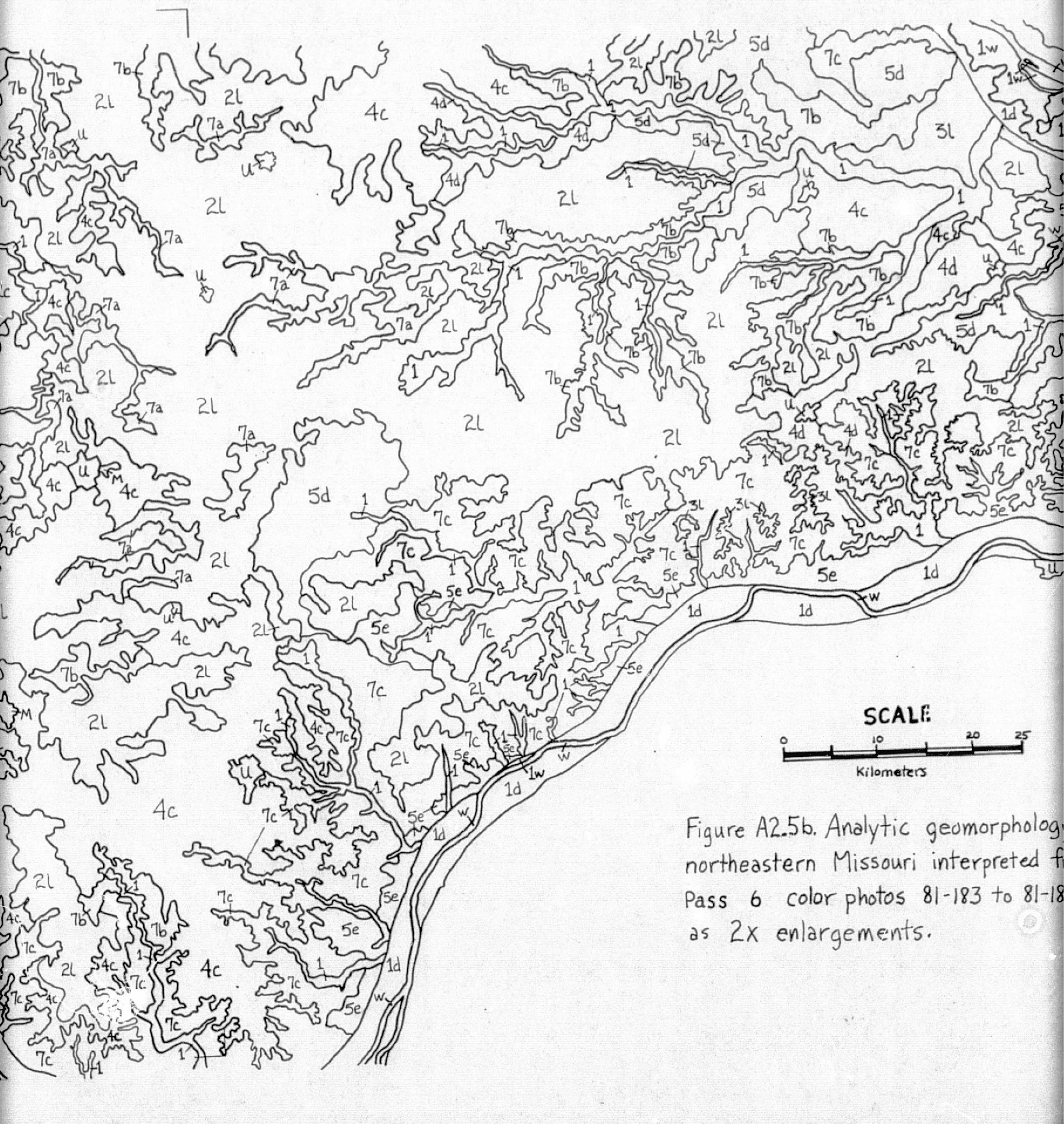

Figure A2.5b. Analytic geomorpholog
northeastern Missouri interpreted f
Pass 6 color photos 81-183 to 81-18
as 2X enlargements.

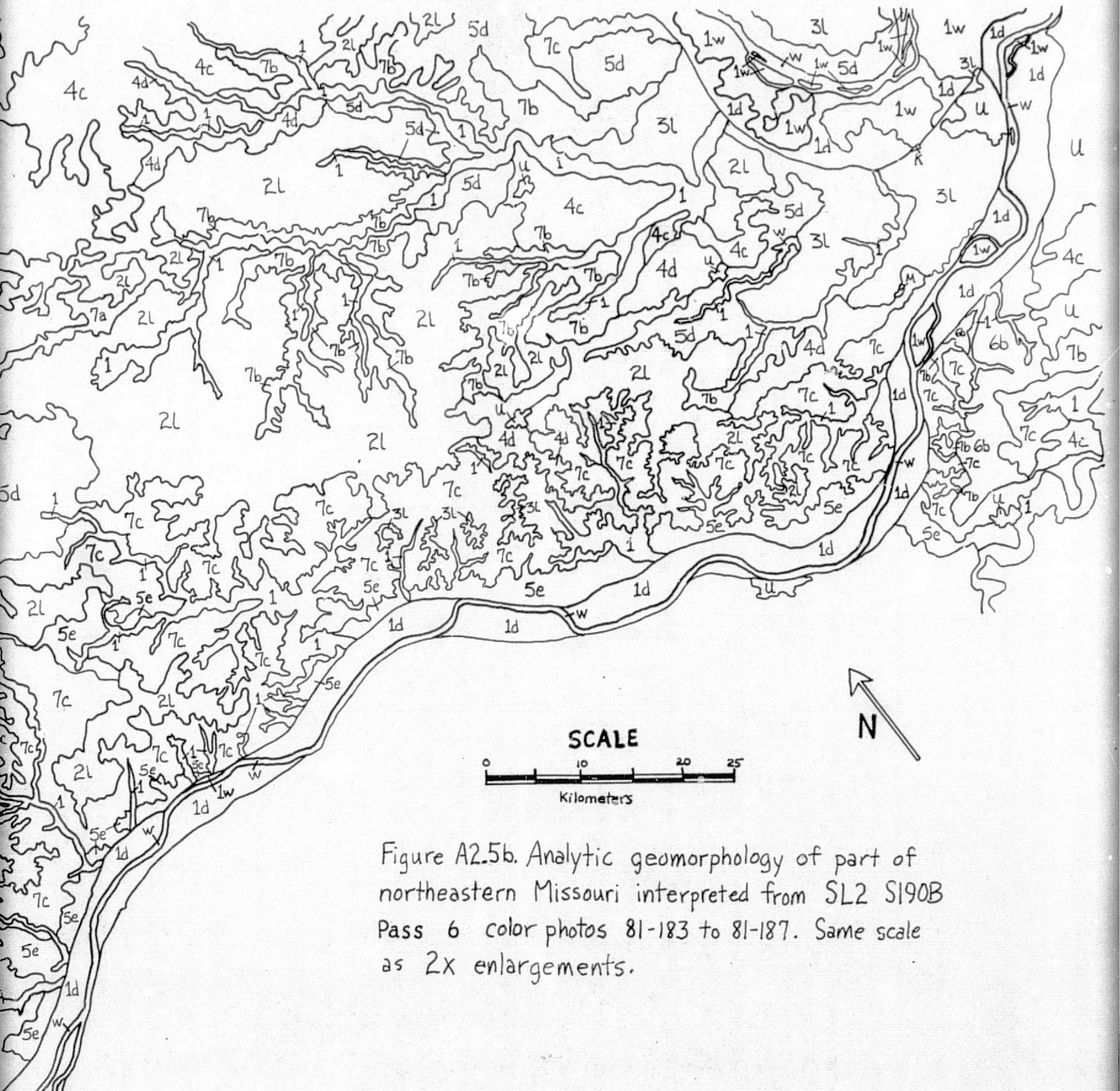

Figure A2.5b. Analytic geomorphology of part of northeastern Missouri interpreted from SL2 S190B Pass 6 color photos 81-183 to 81-187. Same scale as 2x enlargements.

is less reliably informative on topographic detail than it is in some other areas. In regions of generally well-watered productive soils, such as central Illinois (see Appendix article A5), the woodlands are mostly restricted to valley slopes too steep to farm, although narrow "riparian" woodlands also are present along streams subject to frequent flooding. In northeastern Missouri, woodlands occur not only along the steeper valley slopes but also in areas of infertile, highly acid, or poorly drained soils (which can be present in upland summit areas)--thus, their distribution does not necessarily indicate the pattern of steep valley slopes.

Another conclusion reached in evaluating the mapping in northeastern Missouri concerns the limit of our mapping capability. With S190B enlargements (at approximate scale of 1:475,000) of optimum photographic quality, map scale should be no larger than 1:250,000; with good quality S190A enlargements, map scale should be no larger than 1:350,000. The maximum scale of accurate mapping depends primarily on the amount of detail distinguishable in the photos; thus, with the infra-red films (with lowest resolution) the largest feasible map scale is about 1:1,000,000. These scales reflect both the detail discernible from the Skylab photos and the general accuracy of our mapping methods. Greater mapping accuracy could be achieved with better photogrammetric equipment, but this was not available for most of our work. With best-quality S190B photographs and the best stereoplotters, mapping accuracy would not warrant a scale larger than 1:200,000.

A3.0 SIOUX FALLS STUDY AREA, SOUTH DAKOTA AND IOWA

A3.1 Geomorphic setting

The Sioux Falls study area is basically a plain mantled with glacial drift. The drift commonly is less than 30 m thick, but in one place exceeds 145 m. Several major topographic features controlled by the underlying bedrock surface have influenced the directions of glacial flow and the distribution and type of drift. The James River lowland (map unit 1 on Fig. A3.1) provided a channel for the main southward ice movement. Bordering this lowland are moderate highlands of bedrock thinly mantled by drift: the Coteau des Prairies on the east (map unit 2); which extends from North Dakota to northwestern Iowa; and two much more local topographic features, Turkey Ridge (map unit 3) and James Ridge (map unit 4).

The exposed drifts are of three major age groups (Tables A3.1 and A3.2): Illinoian, early Wisconsin, and late Wisconsin. The late Wisconsin drift is by far the most extensive; its drift plain makes up >60% of the area. Three morphogenetic types of this drift are recognized: ground moraine, end moraine, and stagnation moraine. The older drift plains, however, cannot be subdivided, both because of the effects of weathering and erosion, and because the surface exposures are not extensive enough to show major differences in morphology.

Figure A3.1--NEAR HERE
Table A3.1--NEAR HERE
A3.2--NEAR HERE

The Illinoian drift plain is conspicuously light toned in the color photos because of the thick, pale yellowish gray loess mantle that is widely exposed in the uplands. It also is light toned in the CIR and B/W IR bands because the loessial soils are well drained. The Illinoian drift plain also is somewhat higher than the adjoining younger till plains; local relief is greater, commonly more than 30 m; and its stream pattern is denser and well integrated. It has a distinctive topographic grain of parallel, narrow, similar-sized ridges alined northwest-southeast, that probably originated from wind erosion and/or deposition. It is crossed by several wide valleys that contain glacial outwash terraces of Wisconsinan age, namely, the valleys of Big Sioux River, Skunk Creek, Split Rock Creek, and Beaver Creek. Along the northern margin of the Illinoian drift plain a few smaller south-trending outwash channels of Wisconsinan age also can be identified on the Skylab photos. The southern boundary of this drift plain is mostly quite distinct on the SL photos, but the western and northern boundaries in places are indistinct and gradational with the adjoining Wisconsinan drift plains.

The early Wisconsinan drift plain adjoins the Illinoian drift plain to the north. In Skylab color photos it is evenly dark-toned, highlighted by a series of light-toned discontinuous ridges that trend northwest-southeast and lie near and parallel to the boundary with the Illinoian drift plain. Dark-toned flat lowlands separate the ridges. The drainage is moderately well integrated and local relief is less than 20 m. The boundary with the late Wisconsinan drift plain generally is indistinct on all Skylab photos.

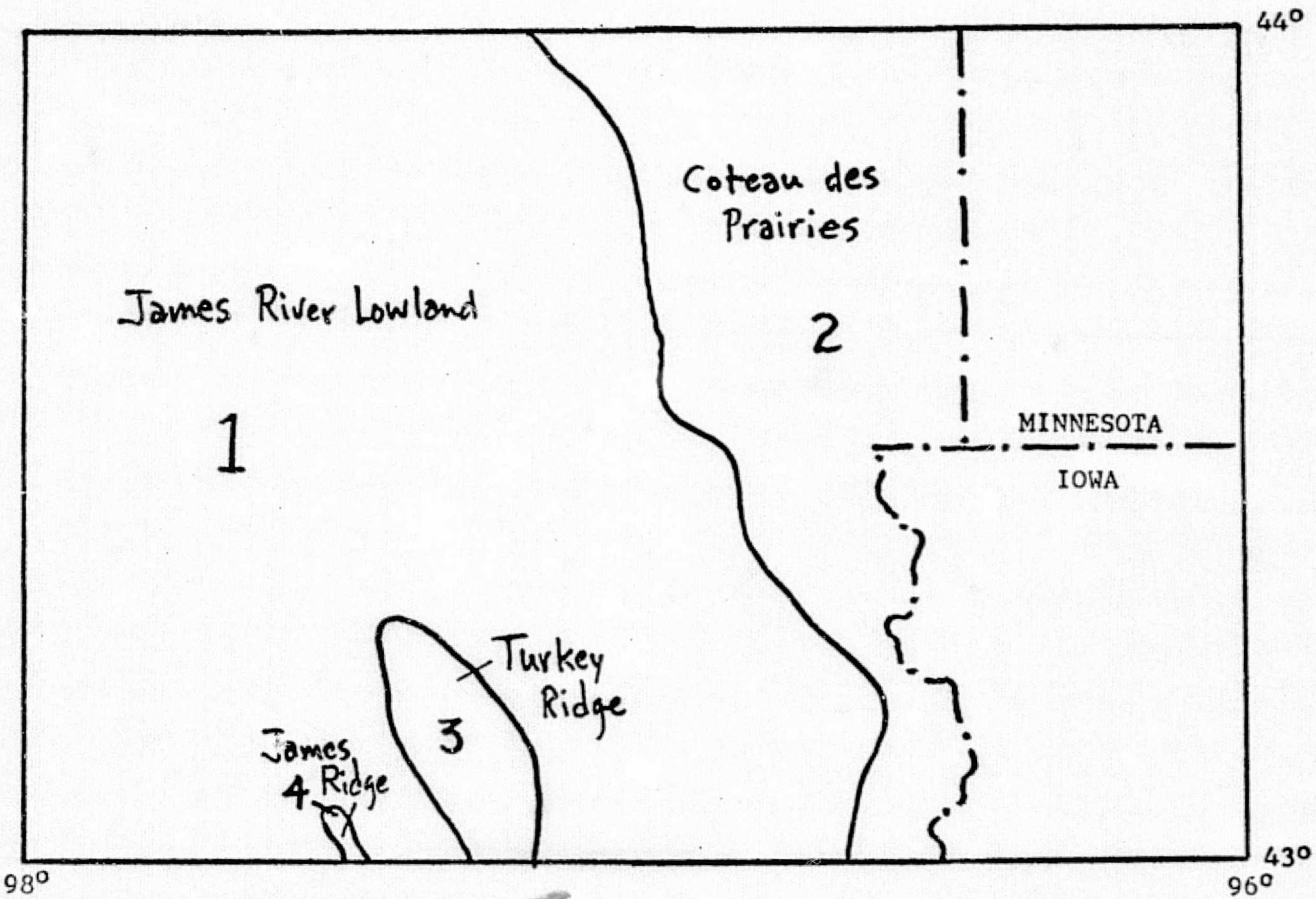

Figure A3.1. Chief landscape units of the Sioux Falls study area.

Table A3.1. Distinguishability of landscape units in the Sioux Falls study area on S190A and S190B photos from various Skylab missions.

PHOTOS			LANDSCAPE UNITS													
SYSTEM	BAND	MISSION	ILLINOIAN DRIFT	EARLY WISCONSINAN DRIFT	LATE WISCONSINAN GROUND MORAINE	LATE WISCONSINAN STAGNATION MORAINE	LATE WISCONSINAN END MORAINE	OUTWASH CHANNELS	OUTWASH PLAINS	GEOLOGIC LINEARS	WATER BODIES	JAMES RIVER TRENCH	TURKEY RIDGE	JAMES RIDGE	URBAN AREAS	FIELD PATTERN CHANGES
S190A	Color	SL2	E	E	G	G	G	G-F	F-P	G	G-F	VG	G	-NC-	G	E
		SL3	VG	G	G	G	G	G	F-P	P	F	VG	-NC-	-NC-	F	VG
		SL4☆	P	P	G	G	G	VG	F-P	G-P	F	VG	G-F	G-F	G	G-F
S190A	CIR	SL2	E	VG	VG	VG	VG	VG	P	G	G-F	E	G	-NC-	G	VG
		SL3	F	P	P	P	P	G	P	F	G-F	E	-NC-	-NC-	F-P	F
		SL4*	P	P	F	F	F	G	P	F-P	P	G	G	G	P	F
S190A	B/W Green	SL2	VG	G-F	G	F	G	G	F-P	G	G	VG	G	-NC-	F	F
		SL3	F-P	F-P	P	P	P	F	P	P	F-P	E	-NC-	-NC-	F	F
		SL4*	P	P	G	G	G	G	P	G	F-P	G	G	G	G-F	G-F
S190A	B/W Red	SL2	G	G	G	G	G	VG	F-P	G	F-P	G	G	-NC-	F	VG
		SL3	F-P	F-P	F	F	F	G	P	G	F	E	-NC-	-NC-	F	F
		SL4☆	P	P	G	G	G	G	P	G	F-P	G	G	VG	G	G-F
S190A	B/W Near IR	SL2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		SL3	P	P	P	P	P	F	P	F	G	G	-NC-	-NC-	P	P
		SL4☆	P	P	F-P	P	P	F-P	P	P	P	G	G-F	G-F	P	F
S190A	B/W Far IR	SL2	F	F-P	F	F	F	G	F-P	P	F	VG	F	-NC-	F-P	F
		SL3*	P	P	P	P	P	F-P	F-P	P	F-P	G	-NC-	-NC-	P	P
		SL4☆	P	P	F	F-P	F-P	G-F	P	P	P	G	G	G	P	F
S190B	Color	SL2	E	E	E	E	E	E	G	E	E	-NC-	-NC-	-NC-	E	E
		SL3	F-P	F-P	G	G	VG	G	F-P	VG	VG	VG	-NC-	-NC-	VG	VG
		SL4☆	G-F	G-F	VG	VG	VG	VG	F	G	G	VG	G	VG	VG	VG

☆ SL4-T30 used for comparing Illinoian and early Wisconsinan drift areas; other comparisons made from evaluating SL4-T19 (1/18/74).
* B/W film.

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Table A3.2. Characteristics of landscape units in the Sioux Falls study area identifiable on SL2-T33 S190A color and color-infrared and S190B photos

LANDSCAPE UNIT	CONTRAST WITH SURROUNDINGS	COLOR VALUE	COLOR		TONE	TONAL PATTERN	FIELD PATTERN	DRAINAGE PATTERN	OTHER IMPORTANT CHARACTERISTICS
			Color film	CIR film					
ILLINOIAN DRIFT	HIGH	BRIGHT	TAN	BLUE	LIGHT-MEDIUM	TRENDING	SOMEWHAT INTERRUPTED	TRELLIS	PERVASIVE NW-SE TREND OF TOPOGRAPHY
EARLY WISCONSINAN DRIFT	LOW	DARK	BROWN & GREEN	BLUE & RED	DARK	SMOOTH	REGULAR	TRELLIS	LINEAR RIDGES TRENDING NW-SE PARALLEL TO S BOUNDARY, OTHERWISE TOPOGRAPHY VERY SUBDUED.
LATE WISCONSINAN GROUND MORAINE	LOW	DARK	BROWN & GREEN	BLUE & RED	DARK	SMOOTH	REGULAR	DERANGED	
LATE WISCONSINAN STAGNATION MORAINE	MEDIUM	MEDIUM	BROWN & GREEN	BLUE & RED	LIGHT-DARK	RANDOMLY MOTTLED	SOMEWHAT INTERRUPTED	DERANGED	SOME E-W TRENDING LINEARS.
LATE WISCONSINAN END MORAINE	HIGH	LIGHT	BROWN & GREEN	BLUE & RED	LIGHT-MEDIUM	TRENDING MOTTLES	SOMEWHAT INTERRUPTED	DERANGED	LOCALIZED GROUPS OF RIDGES WITH SIMILAR TRENDS.
OUTWASH CHANNELS	MEDIUM	DARK	BROWN & GREEN	BLUE & RED	DARK	SMOOTH	REGULAR	—	USUALLY BOUNDED BY SHARP CHANGE IN TONE AND PATTERN.
OUTWASH PLAINS	LOW	DARK	BROWN & GREEN	BLUE & RED	MEDIUM-DARK	SMOOTH	FAIRLY REGULAR	DENDRITIC	FAIRLY SMALL USUALLY WITH LAKE NEAR CENTER.
GEOLOGIC LINEARS	MEDIUM	LIGHT	—	—	LIGHT	TRENDING	—	—	WIDELY VARIABLE IN LENGTH, MOSTLY TRENDING NW-SE.
WATER BODIES	MEDIUM	DARK	BLUE-BLACK	BLACK	DARK	SMOOTH	—	—	
JAMES RIVER TRENCH	MEDIUM-HIGH	DARK	BROWN & GREEN	BLUE & RED	DARK	SMOOTH	REGULAR	—	VERY CONSTANT IN WIDTH.
TURKEY RIDGE	MEDIUM-LOW	MEDIUM	BROWN & GREEN	BLUE & RED	LIGHT-MEDIUM	LIGHT RANDOM MOTTLES	VERY INTERRUPTED	TRELLIS	NORTH AND NORTHWEST SLOPES RIMMED BY LATE WISCONSINAN END MORAINE.
JAMES RIDGE	MEDIUM-LOW	MEDIUM	BROWN & GREEN	BLUE & RED	LIGHT-MEDIUM	LIGHT RANDOM MOTTLES	VERY INTERRUPTED	RADIAL	ALIGNMENT PARALLEL TO TURKEY RIDGE, ALSO RIMMED WITH LATE WISCONSINAN END MORAINE.
URBAN AREAS	MEDIUM	LIGHT	GREY	GREY	LIGHT	GRIDDED	—	—	RECENTLY DEVELOPED AREAS SHOW AS CONSPICUOUSLY LIGHTER TONES.

The late Wisconsinan drift plain is mostly dark toned in color photos, though in places somewhat variable in tone. Within the James River lowland it is mostly gently undulating to nearly level, with local relief less than 10 m, although in small areas relief attains 20 m and even (rarely) 30 m. Streams are relatively few and undrained depressions numerous.

The late Wisconsin drift plain has the least well integrated drainage system and the widest morphological variety: ground moraine, end moraine, stagnation moraine, and outwash plains and channels. The differences between ground, end, and stagnation moraines can be noted in topography, drainage, land use, and tonal variations on different bands. Ground moraine has a dark, even tone, a manifestation of its low local relief, poorly integrated drainage, and widespread poorly drained soils. End moraines usually appear on the photos as discontinuous areas of medium dark tones with light-toned elongate mottles; topographic maps show the end moraines as discontinuous gently rolling low hills with fairly well integrated drainage. Stagnation moraines have very poorly integrated drainage, which shows on the photographs as an over-all dark tone, locally on the steeper, better-drained slopes mottled with randomly shaped, sized, and spaced lighter tones.

Other features mapped from the photos are outwash channels and plains, steeply sloping gullied river bluffs, urban areas, and geologic linears; also, in areas with adequate S190B coverage, river terraces.

A3.2 Coverage by Skylab photos and topographic and geologic maps

Coverage of the Sioux Falls $1^{o} \times 2^{o}$ quadrangle is limited to the following flights: SL2 Pass 6 (Track 19), SL2 Pass 7 (Track 33), SL3 Pass 31 (Track 30/16), SL4 Pass 54 (Track 19), SL4 Pass 85 (Track 19), and SL4 Pass 83 (Track 30) and is shown in Fig. A3.2(A). SL2 Pass 6 (Track 19) covered only a little of the SW corner of the study area. One hundred percent cloud cover over the northwest third of the quad restricts the otherwise excellent SL2 Pass 7 (Track 33) coverage to the eastern two-thirds of the quad. SL3 Pass 31 (Track 30/16) covered the northwest half of the area (although there are scattered clouds in the extreme northwest corner and haze over 75% of the remaining area); the S190B (with high resolution B/W film) has 60% overlap and is much more useful than the S190A which has only 10% overlap. SL4 Pass 54 (Track 19, November, 1973) covers only a tiny part of the SW corner; SL4 Pass 85 (Track 19, January, 1974), shows more of the southwest corner but is 60% snow-covered, and the snow-covered areas are badly overexposed; SL4 Pass 83 (Track 30) covers much of the study area, but it has 100% snow cover and is so overexposed that it is essentially useless. Useful coverage was therefore limited to SL2 Pass 7 (Track 33), SL3 Pass 31 (Track 30/16) S190B (although S190A was studied without stereo to compare film qualities), and SL4 Pass 85 (Track 19, January, 1974). Obviously, our comparison of different bands at different seasons could have been much more complete if the SL3 Pass 31 S190A films had had more stereo overlap, and if SL4 snow-covered photographs had been properly exposed.

Part B of Fig. A3.2 shows the coverage of the Sioux Falls $1^{o} \times 2^{o}$ quadrangle by 7 1/2-minute topographic quadrangle maps, and part C shows the coverage by published geologic maps.

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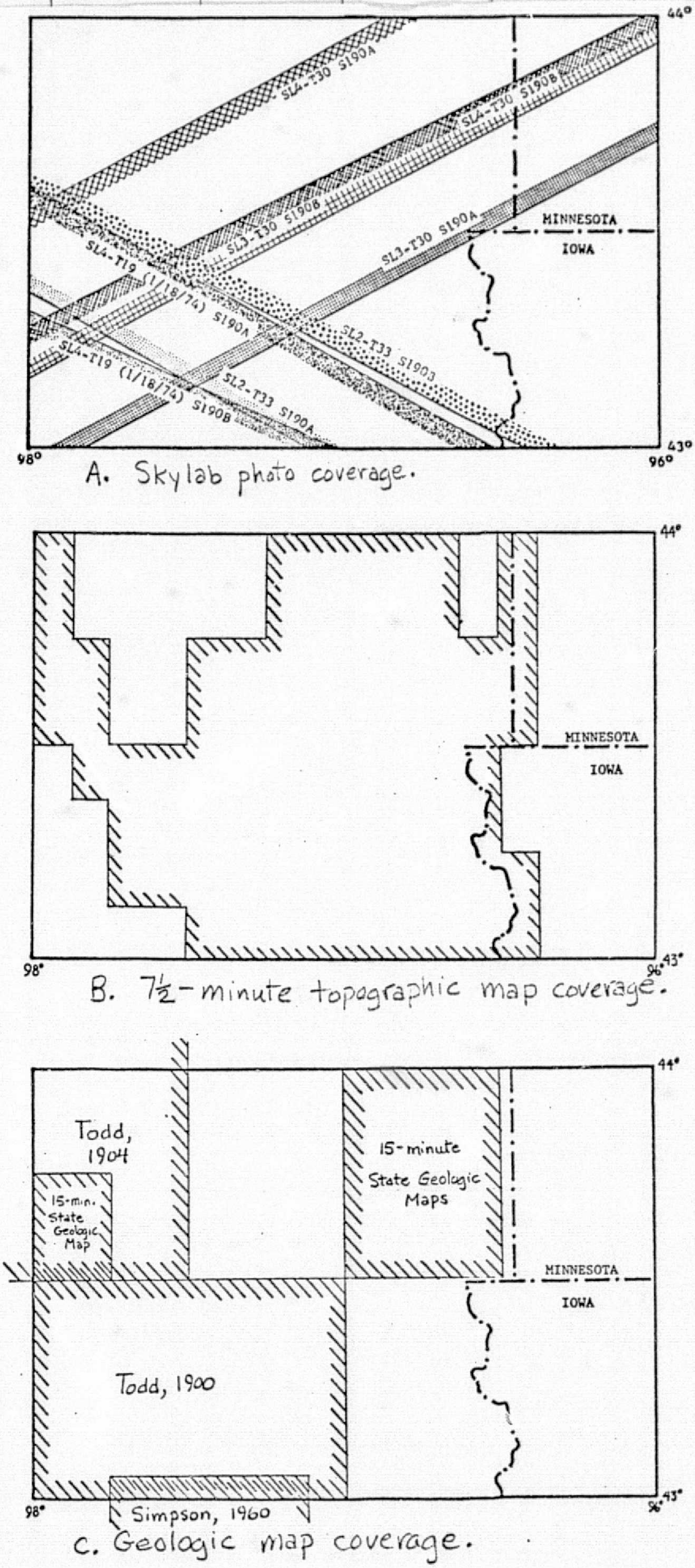

Figure A3.2. Coverage of the Sioux Falls study area by Skylab photos (A) and topographic (B) and geologic maps (C).

A3.3 Interpretive procedure

To familiarize ourselves with the area we first compiled a land-surface-form map of the Sioux Falls $1^{o} \times 2^{o}$ quadrangle from available 7 1/2-minute topographic quadrangle maps (Fig. A3.3). We examined SL2 Pass 7 (Track 33) S190B frames 81-315 to 81-317 (unenlarged) with a Kern PG-2 stereoplotter; this phase of the study produced a map of analytic geomorphology at 1:250,000 scale (Fig. A3.4). Then S190A and S190B enlargements were studied with an Old Delft scanning stereoscope, and analytic geomorphology was mapped on transparent overlays (at photo scale). Copies of these overlays were sent to the South Dakota State Geological Survey where they were analyzed for accuracy of boundary delineation and map unit classification. With this additional "ground control" the final copies of the overlays were produced (Figs. A3.5 and A3.6).

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A3.6--NEAR HERE

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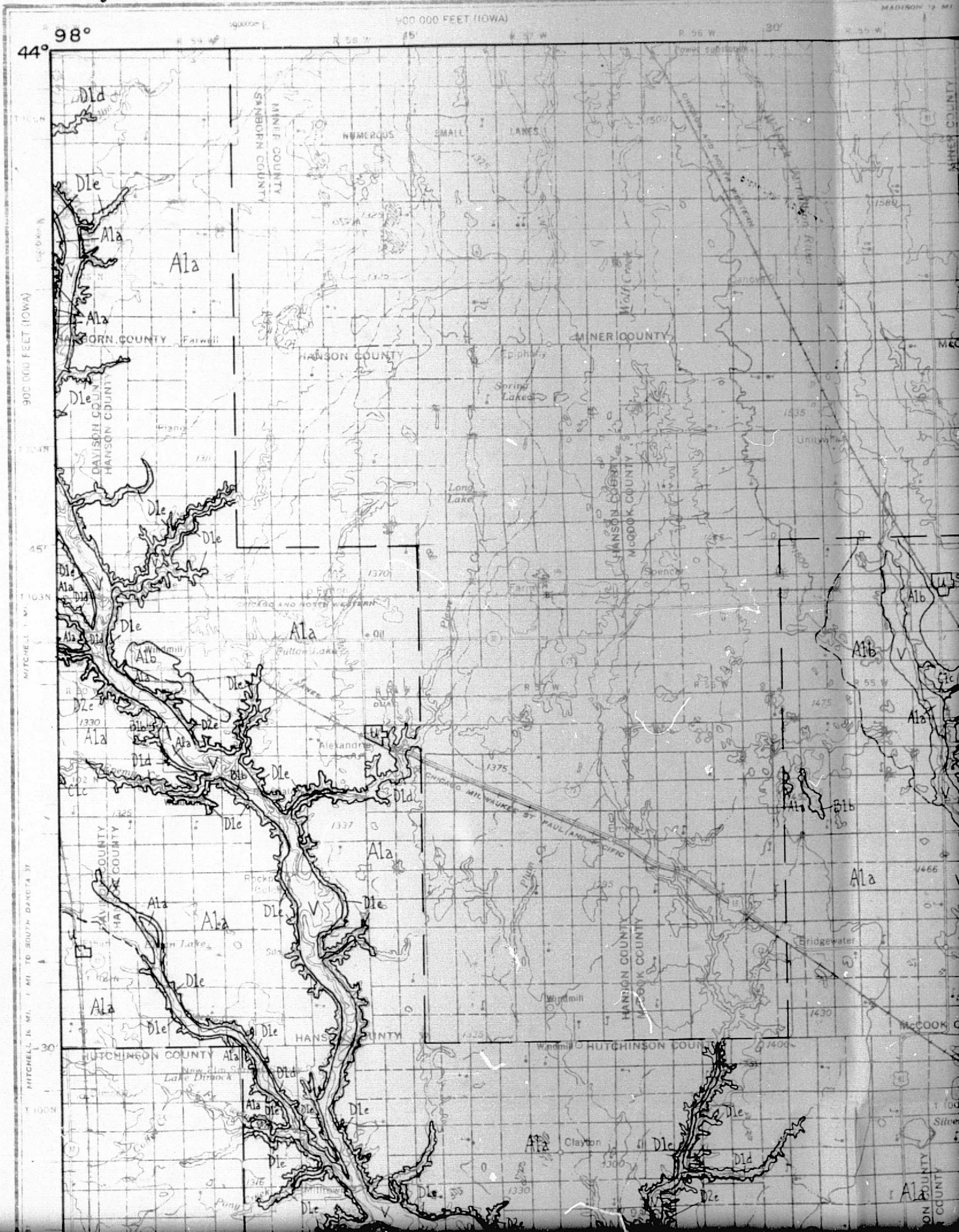
Figure A3.3



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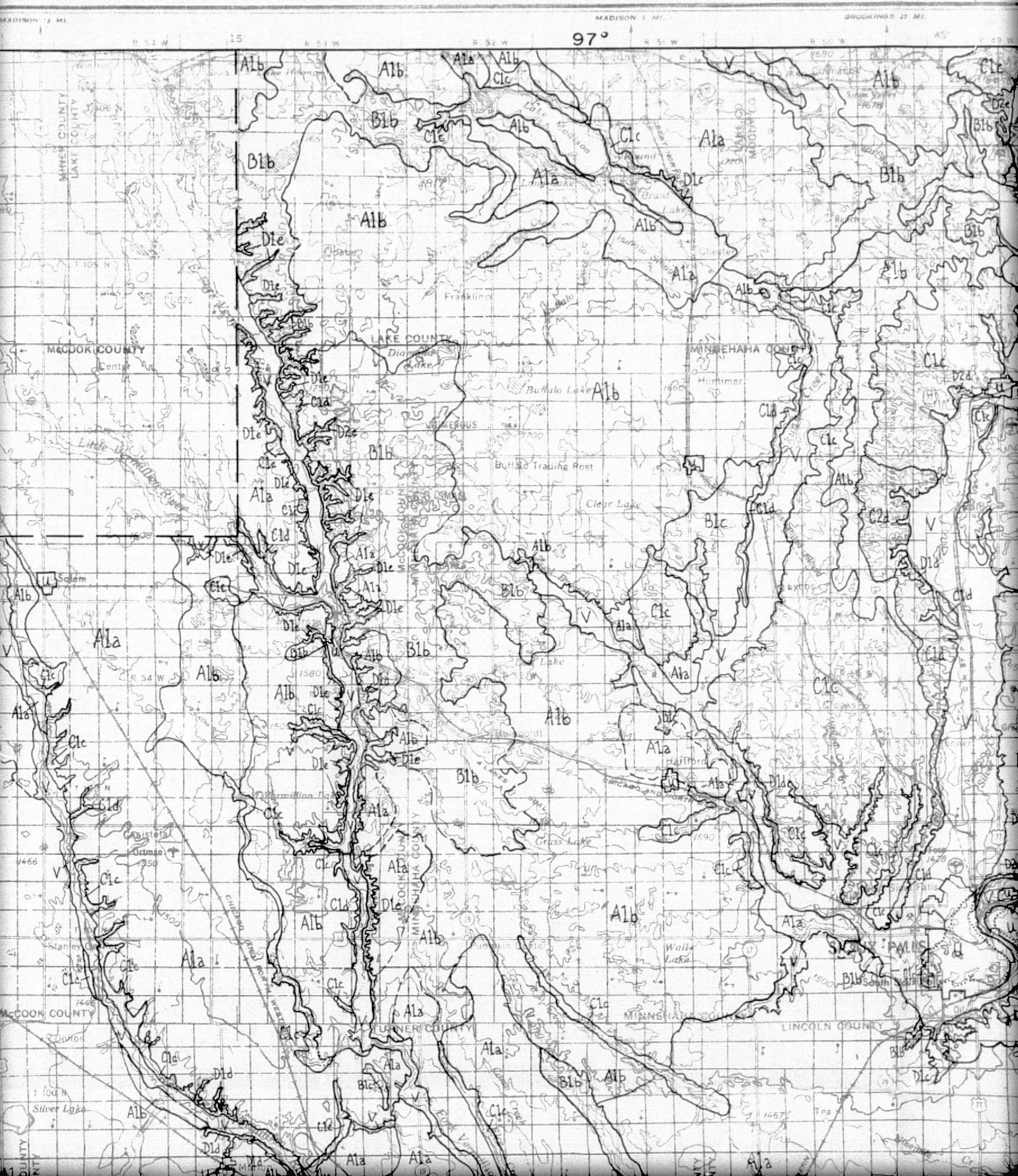
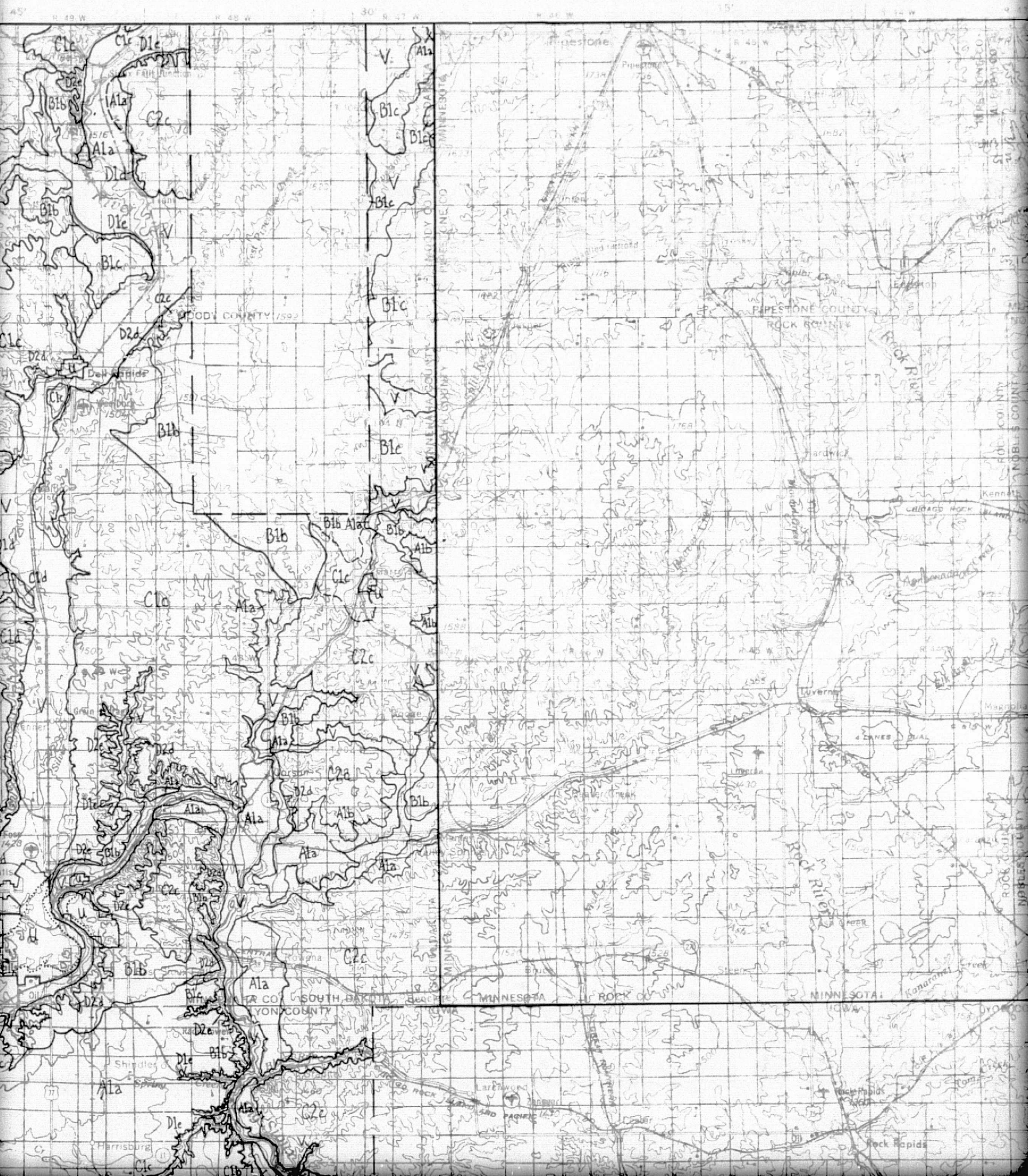
SIOUX FALLS



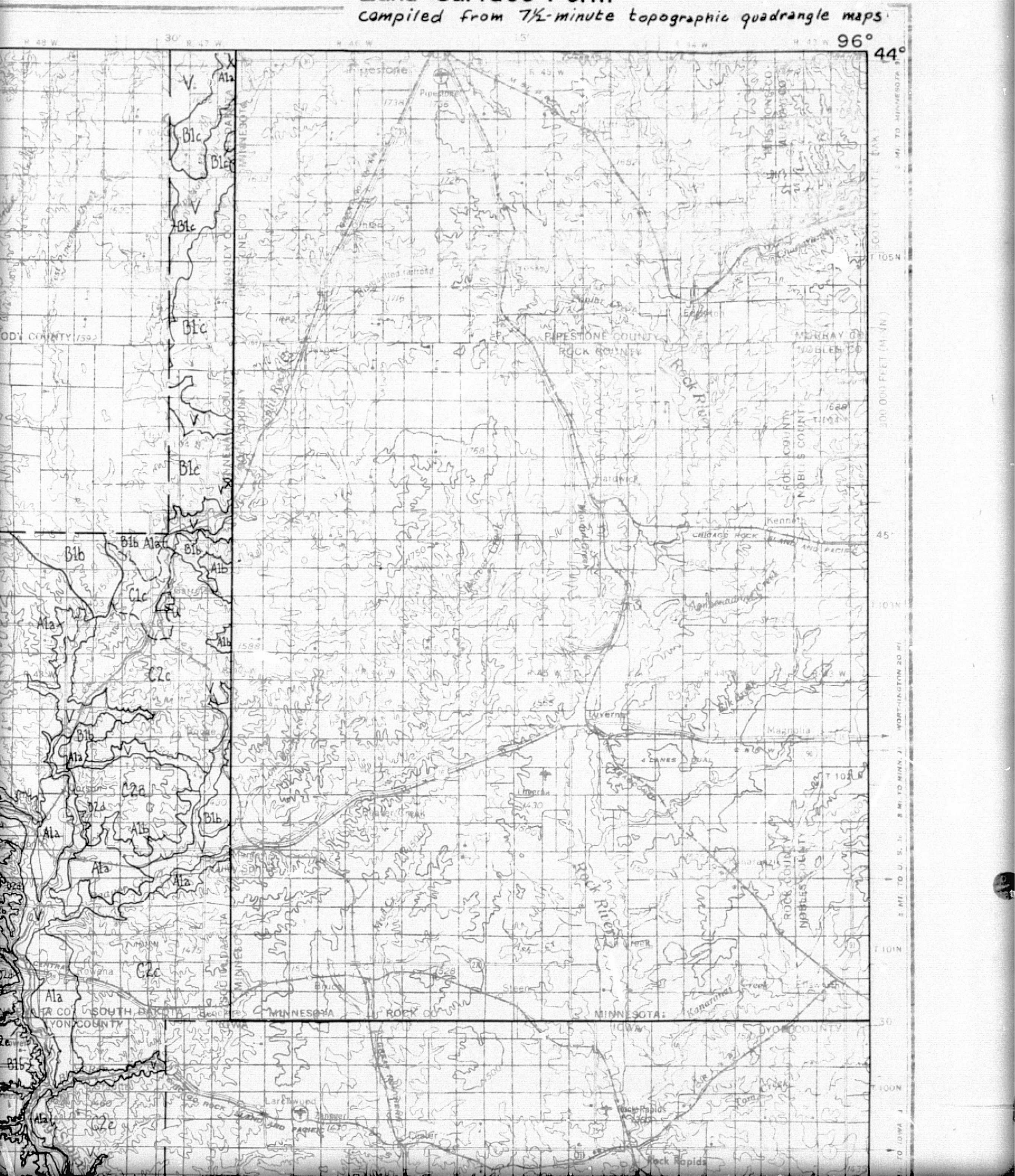
Land-Surface Form

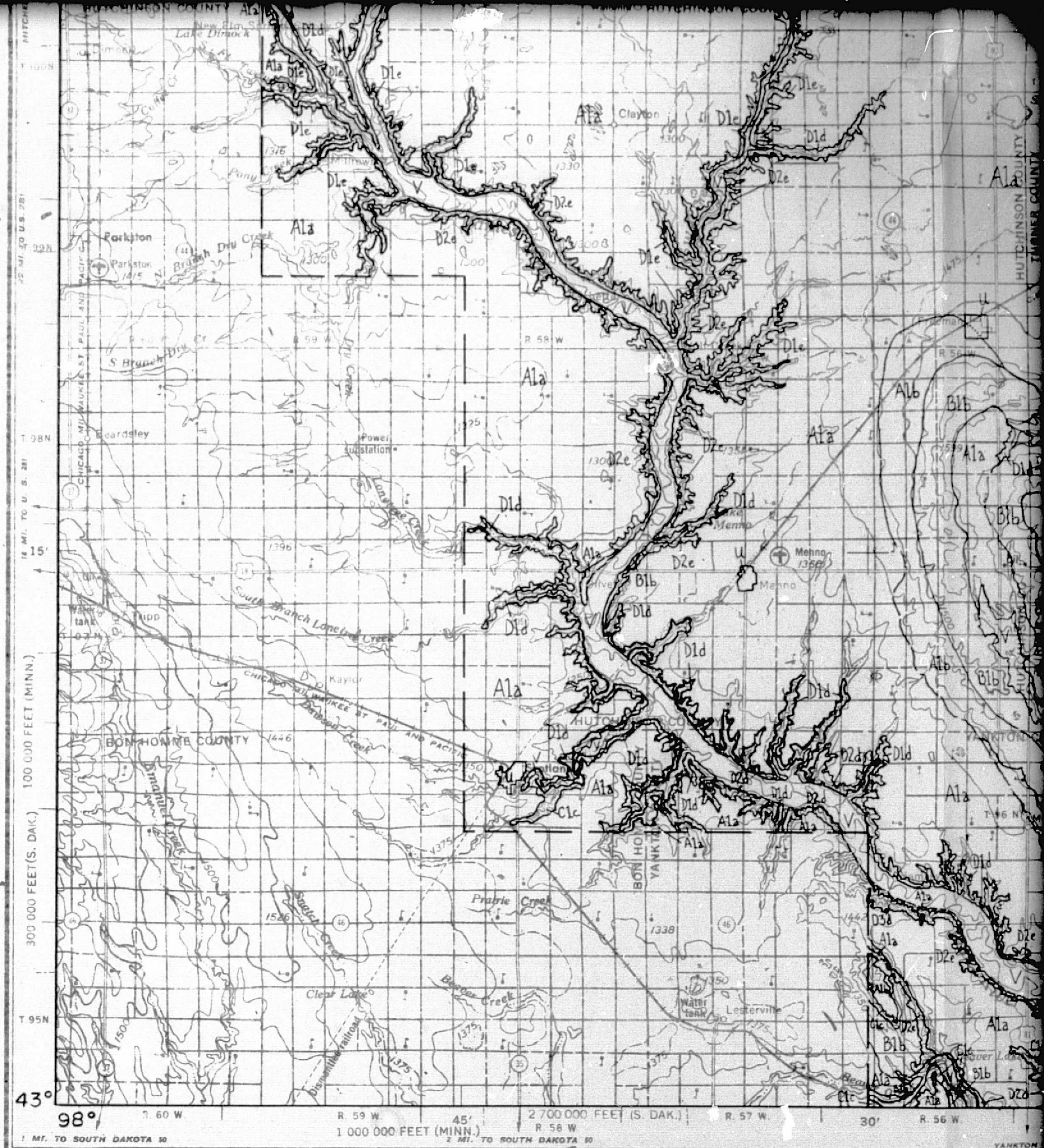
compiled from 7½-minute topographic quadrang



Land-Surface Form

compiled from 7½-minute topographic quadrangle maps





Prepared by the Army Map Service (ASSX), Corps of Engineers, U.S. Army, Washington, D.C. Compiled in 1955 by photogrammetric methods and from United States quadrangles, 1:125,000, 1896-97. Planimetric detail revised by photo-planimetric methods. Horizontal and vertical control by USGS and USCE. Photography field annotated 1955. Limited revision by U.S. Geological Survey 1966.

100,000-foot grids based on South Dakota coordinate system, south zone, Iowa coordinate system, north zone, and Minnesota coordinate system, south zone

10,000-meter Universal Transverse Mercator grid ticks, zone 14, shown in blue

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LEGEND

ROAD DATA 1955 PARTIALLY REVISED 1966

POPULATED PLACES

Over 500,000 LOS ANGELES

100,000 to 500,000 OMAHA

25,000 to 100,000 GALVESTON

5,000 to 25,000 Laramie

1,000 to 5,000 Grand Coulee

Less than 1,000 Sun Valley

RAILROADS

Single track Double or Multiple

Standard gauge

Narrow gauge

BOUNDARIES

International

State

County

Park or reservation

ROADS

Hard surface, heavy duty

More than two lanes wide

Two lanes wide; Federal route marker

Hard surface, medium duty

More than two lanes wide

Two lanes wide; State, Interstate route

Improved light duty

Unimproved dirt

Trail

Landplane airport

Landing area

Seaplane airport

Seaplane anchorage

Woods-brushwood

Landmarks: Scho

Horizontal control

Spot elevation in

Marsh or swamp

Intermittent or dr

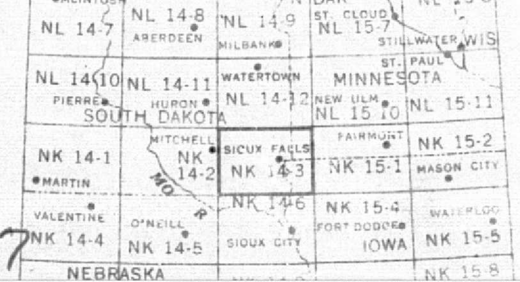
Power line

20 Statute Miles

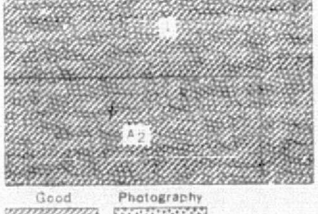
30 Kilometers

Nautical Miles

LOCATION DIAGRAM



RELIABILITY DIAGRAM



Good

Photography

A. Medium scale topographic maps, controlled ground survey, 1896-97.

1. Stereo compiled from 1953 aerial photography.

TOWNSHIP OR RANGE LINE

LAND GRANT BOUNDARY

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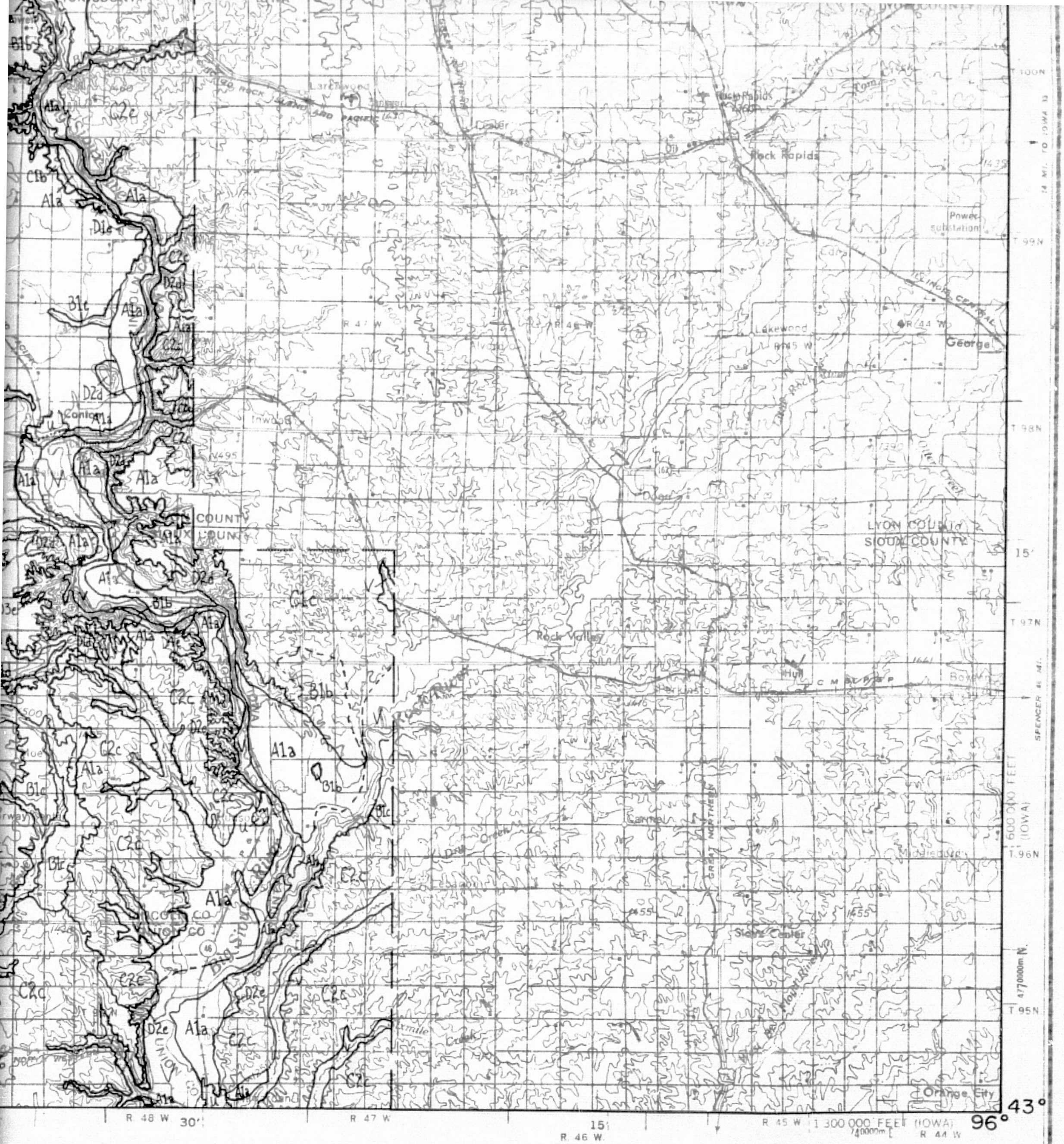
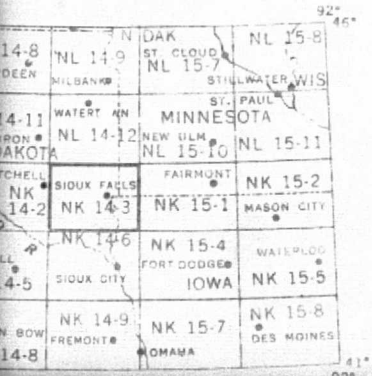


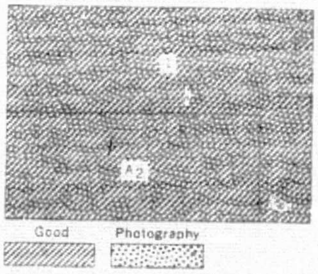
SPECIAL PRINTING
Contours and woodland symbols omitted

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1967

LOCATION DIAGRAM



RELIABILITY DIAGRAM



A. Medium scale topographic maps, controlled ground survey, 1896-97.
1. Stereo compiled from 1953 aerial photography.
2. Planimetry revised from 1953 aerial photography.

TOWNSHIP OR RANGE LINE

LAND GRANT BOUNDARY

SECTIONIZED TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

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SIOUX FALLS, SOUTH DAKOTA, IOWA; MINNESOTA

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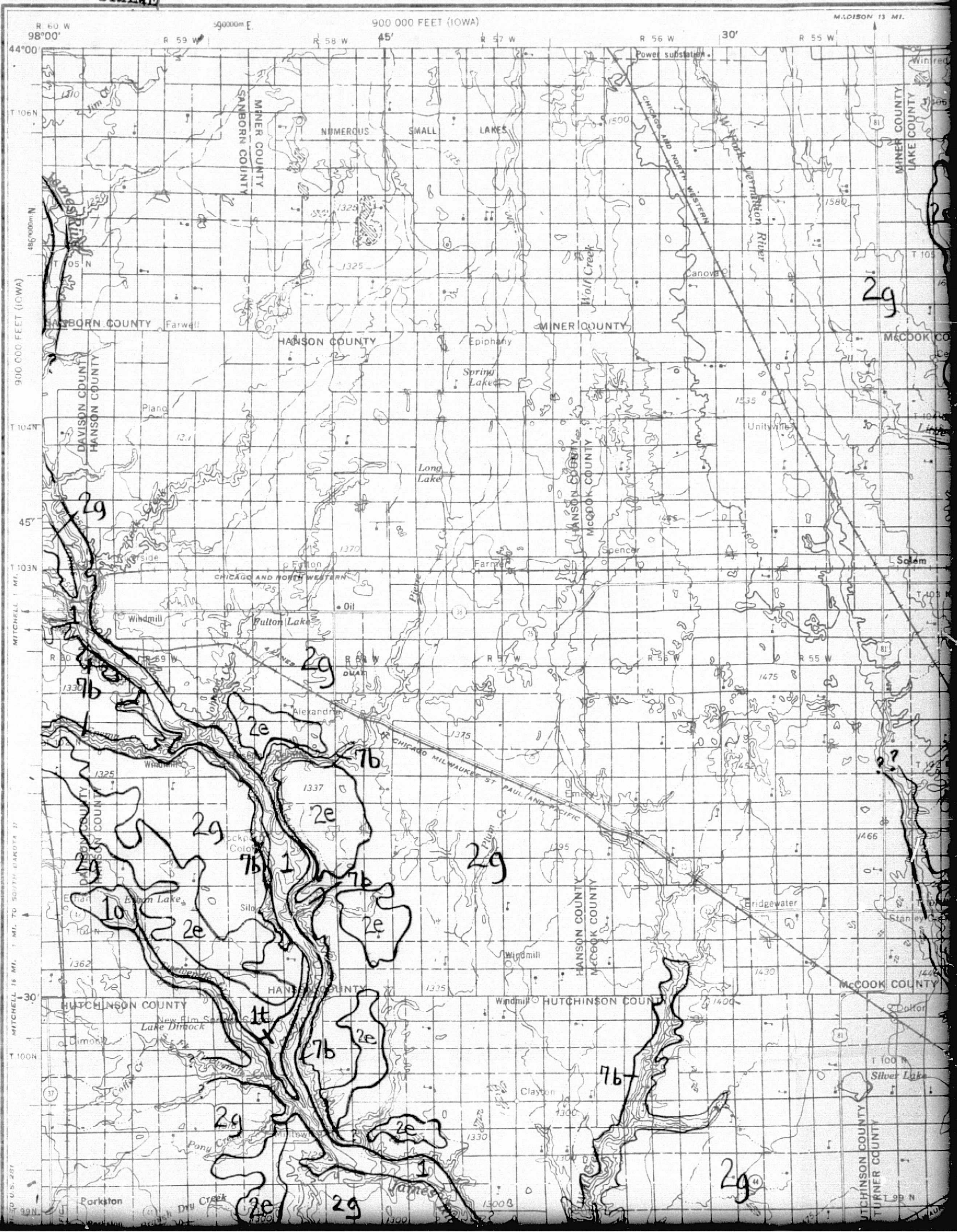

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SIOUX FALLS

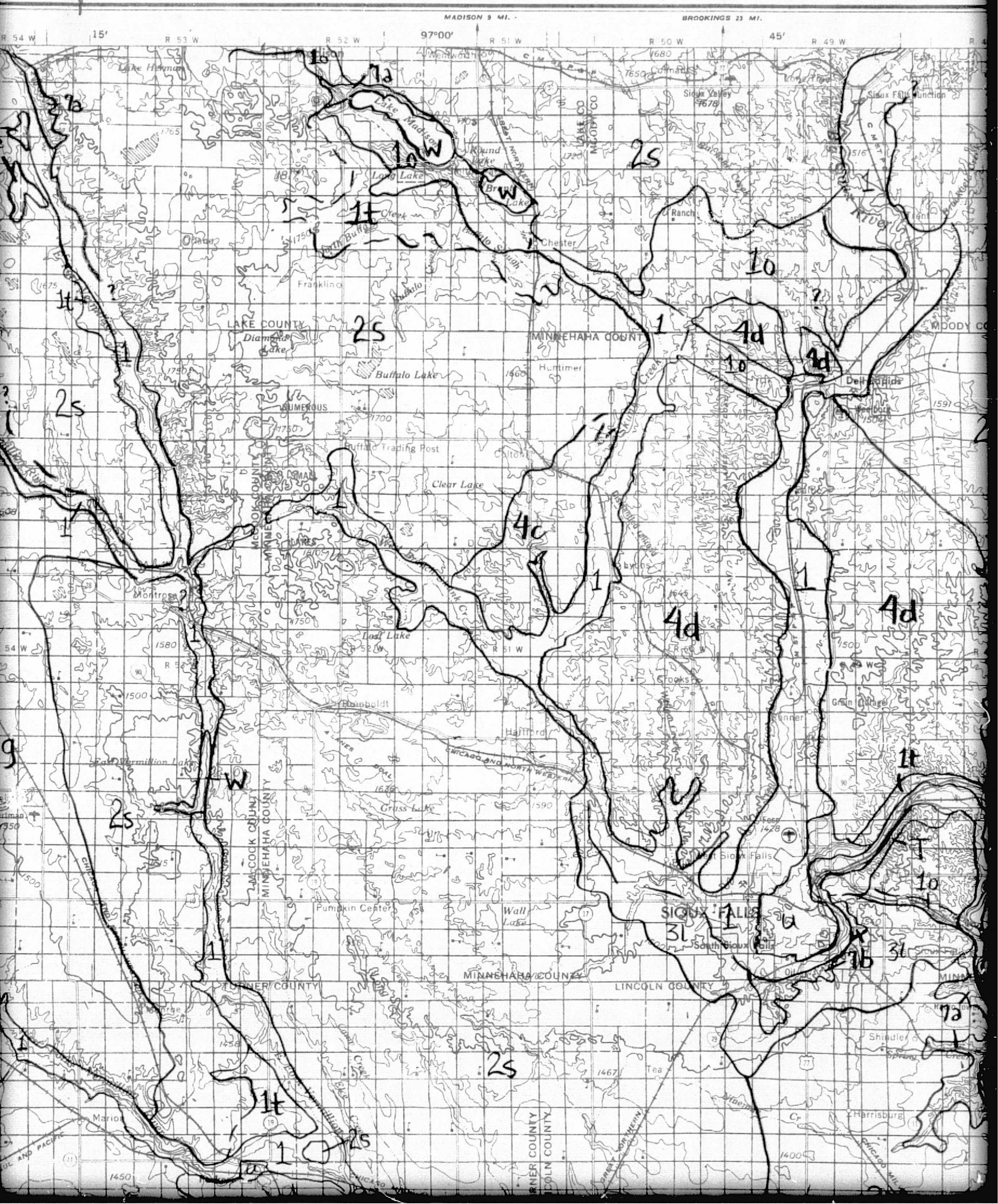

Figure A3.4. Analytic Geomorphology (interpreted from all the most useful SL photos using a Kern PG-2 stereoplotter.)

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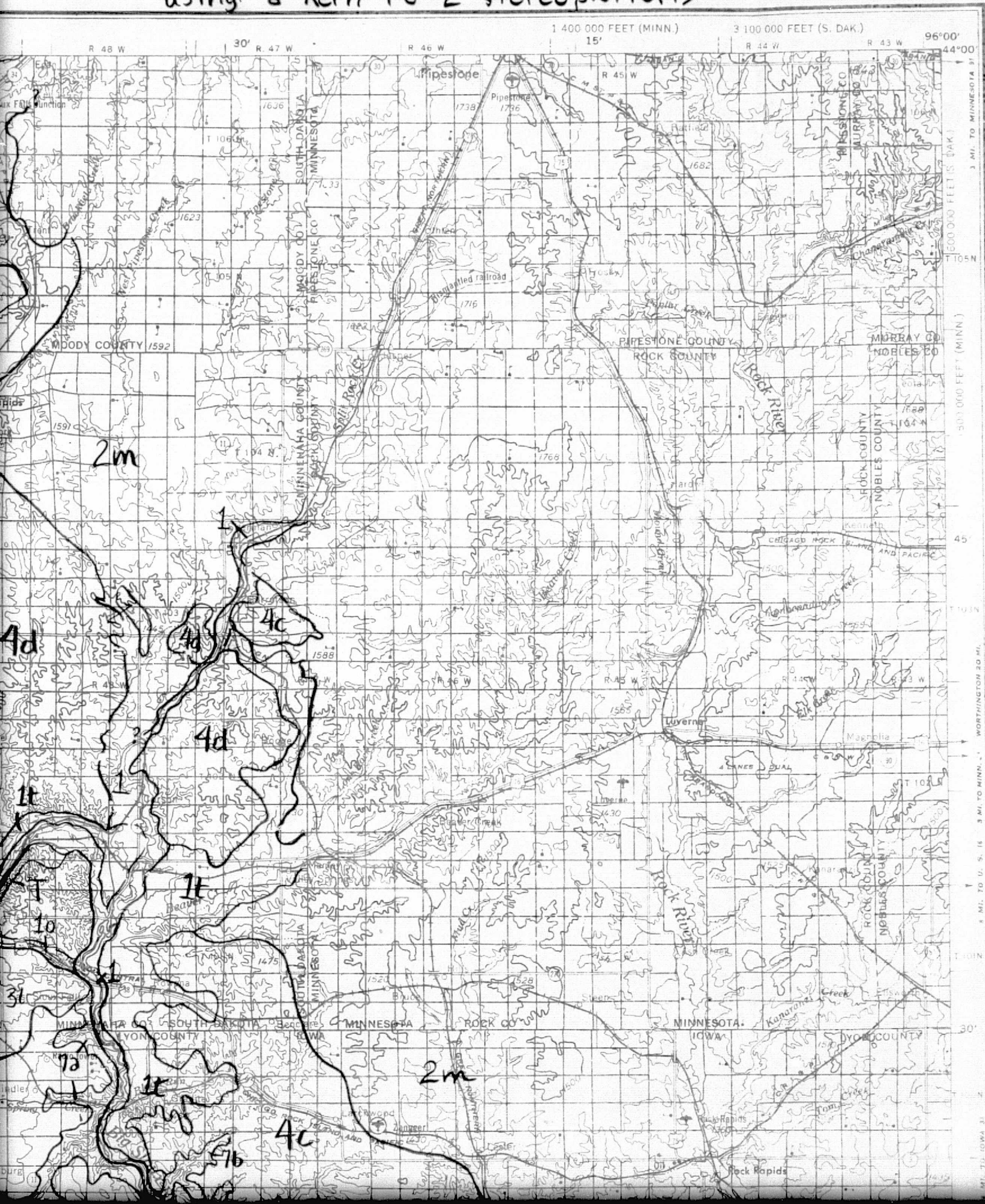
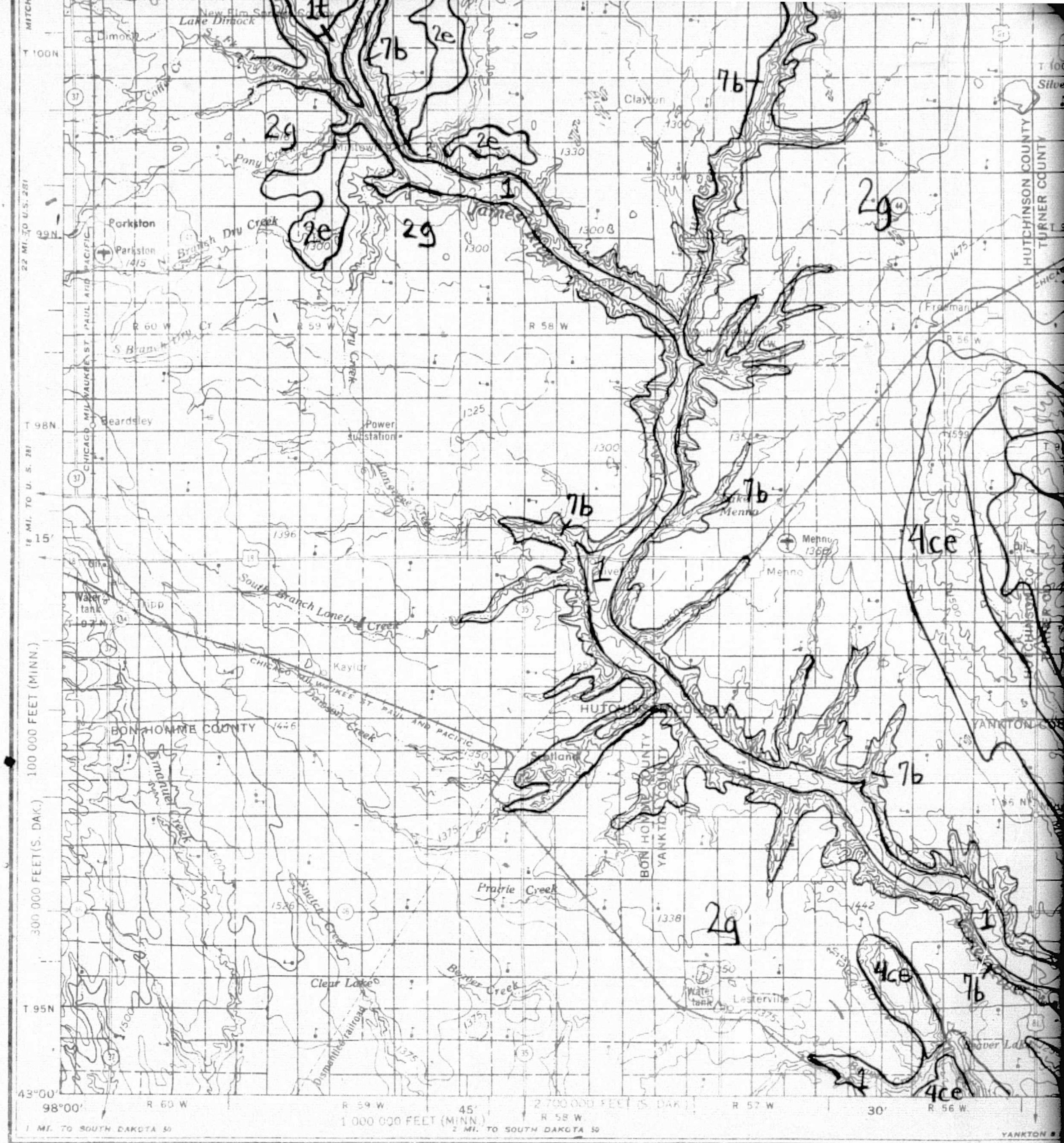




Prepared by the Army Map Service (ASSX), Corps of Engineers, U.S. Army, Washington, D.C. Compiled in 1955 by photogrammetric methods and from United States quadrangles, 1:125,000, 1896-97. Planimetric detail revised by photo-planimetric methods. Horizontal and vertical control by USGS and USCE. Photography field annotated 1955. Limited revision by U.S. Geological Survey 1966.

100,000-foot grids based on South Dakota coordinate system, south zone, Iowa coordinate system, north zone, and Minnesota coordinate system, south zone.

10,000-meter Universal Transverse Mercator grid ticks, zone 14, shown in blue.

LEGEND

ROAD DATA 1955 PARTIALLY REVISED 1966

POPULATED PLACES

Over 500,000 — LOS ANGELES

100,000 to 500,000 — OMAHA

25,000 to 100,000 — GALVESTON

5,000 to 25,000 — Laramie

1,000 to 5,000 — Grand Coulee

Less than 1,000 — Sun Valley

RAILROADS

Single track / Double or Multiple

Standard gauge

Narrow gauge

BOUNDARIES

International

State

County

Park or reservation

ROADS

Hard surface, heavy duty

More than two lanes wide

Two lanes wide; Federal route marker

Hard surface, medium duty

More than two lanes wide

Two lanes wide; State, interstate route m

Improved light duty

Unimproved dirt

Trail

Landplane airport

Landing area

Seaplane airport

Seaplane anchorage

Woods-brushwood

Landmarks: School

Hor ntal control p

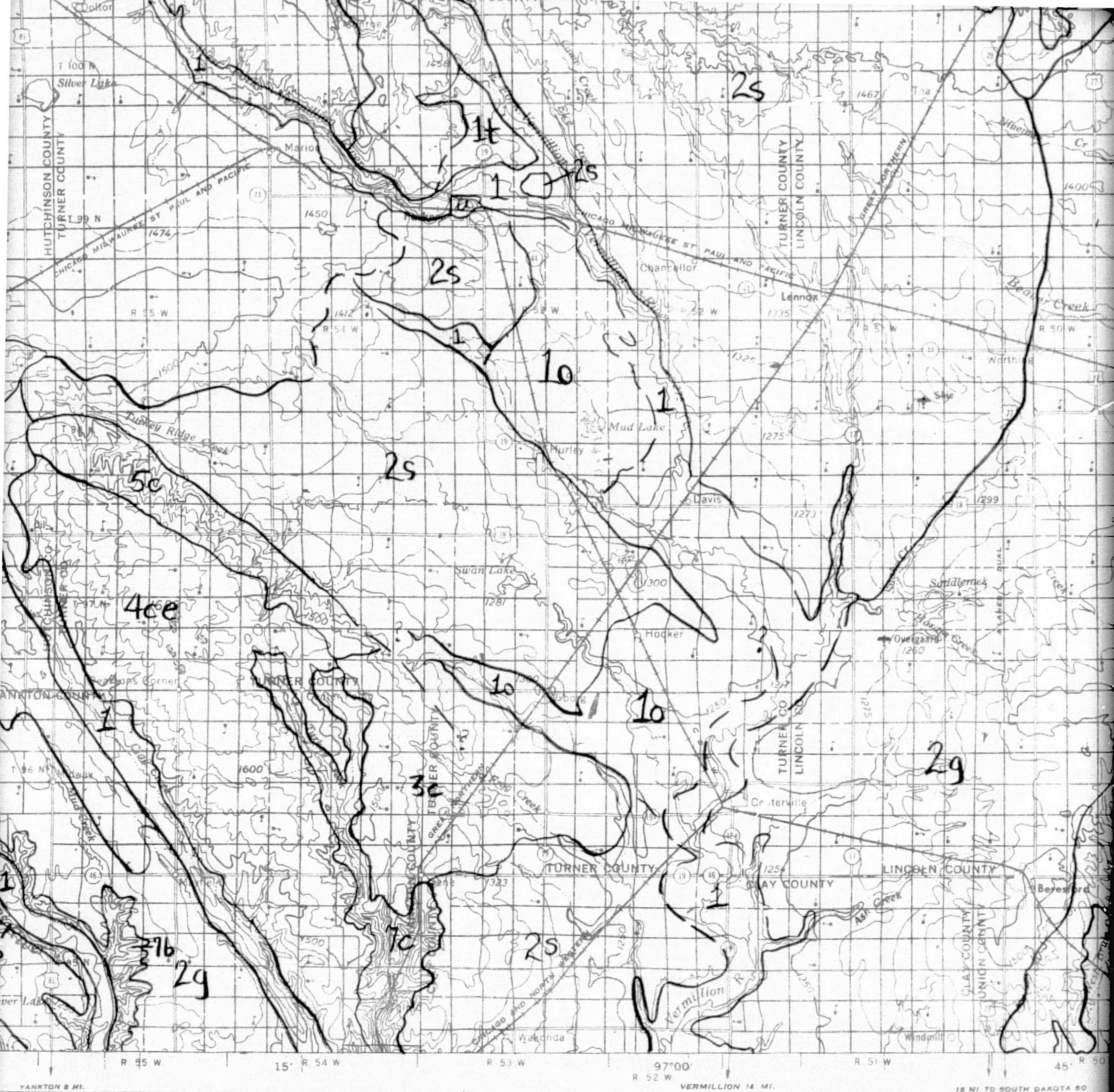
Spot elevation in fe

Marsh or swamp

Intermittent or dry s

Power line

FOLDOUT FRAME 4



Scale 1:250,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilometers

5 0 5 10 15 Nautical Miles

route marker

3 LANES | 4 LANES

terstate route markers

marks: School; Church; Other

zontal control point

elevation in feet

h or swamp

mittent or dry stream

r line

CONTOUR INTERVAL 50 FEET

WITH SUPPLEMENTARY CONTOURS AT 25 FOOT INTERVALS

TRANSVERSE MERCATOR PROJECTION

1965 MAGNETIC DECLINATION FROM TRUE NORTH FOR THIS SHEET VARIES FROM 9½° (170 MILS) EASTERLY FOR THE CENTER OF THE WEST EDGE TO 8° (140 MILS) EASTERLY FOR THE CENTER OF THE EAST EDGE

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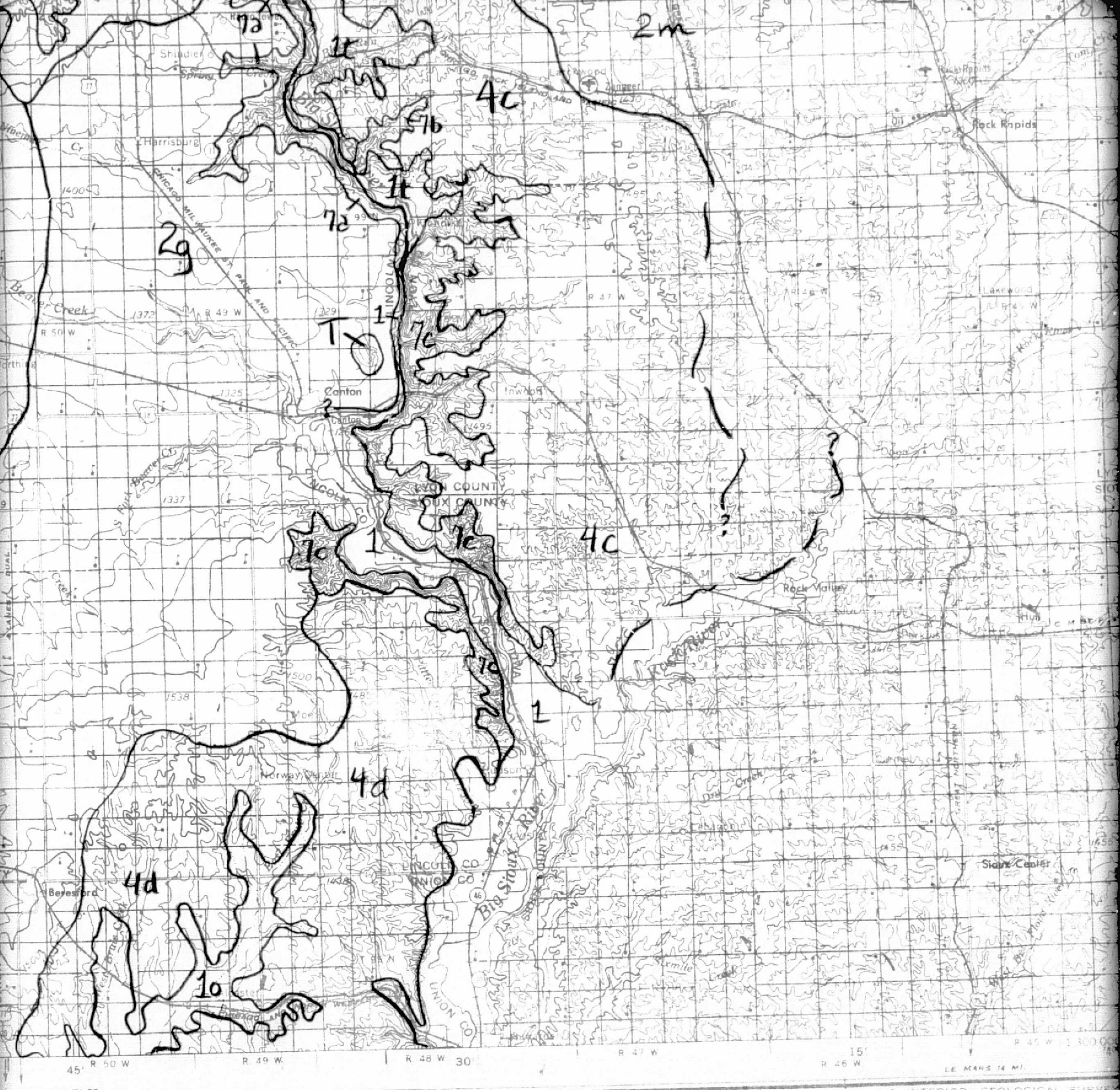
FOLDOUT FRAME 5

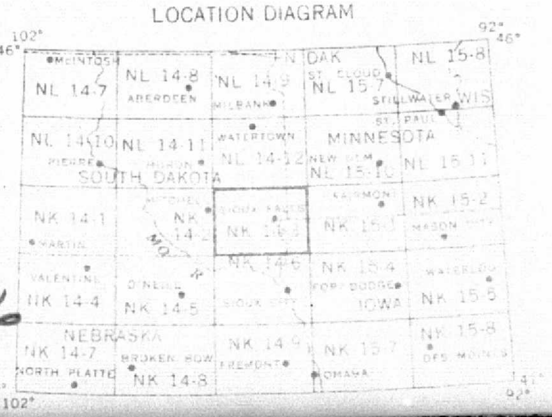


20 Statute Miles

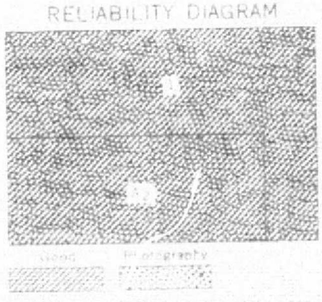
30 Kilometers

Nautical Miles

LOCATION DIAGRAM



RELIABILITY DIAGRAM



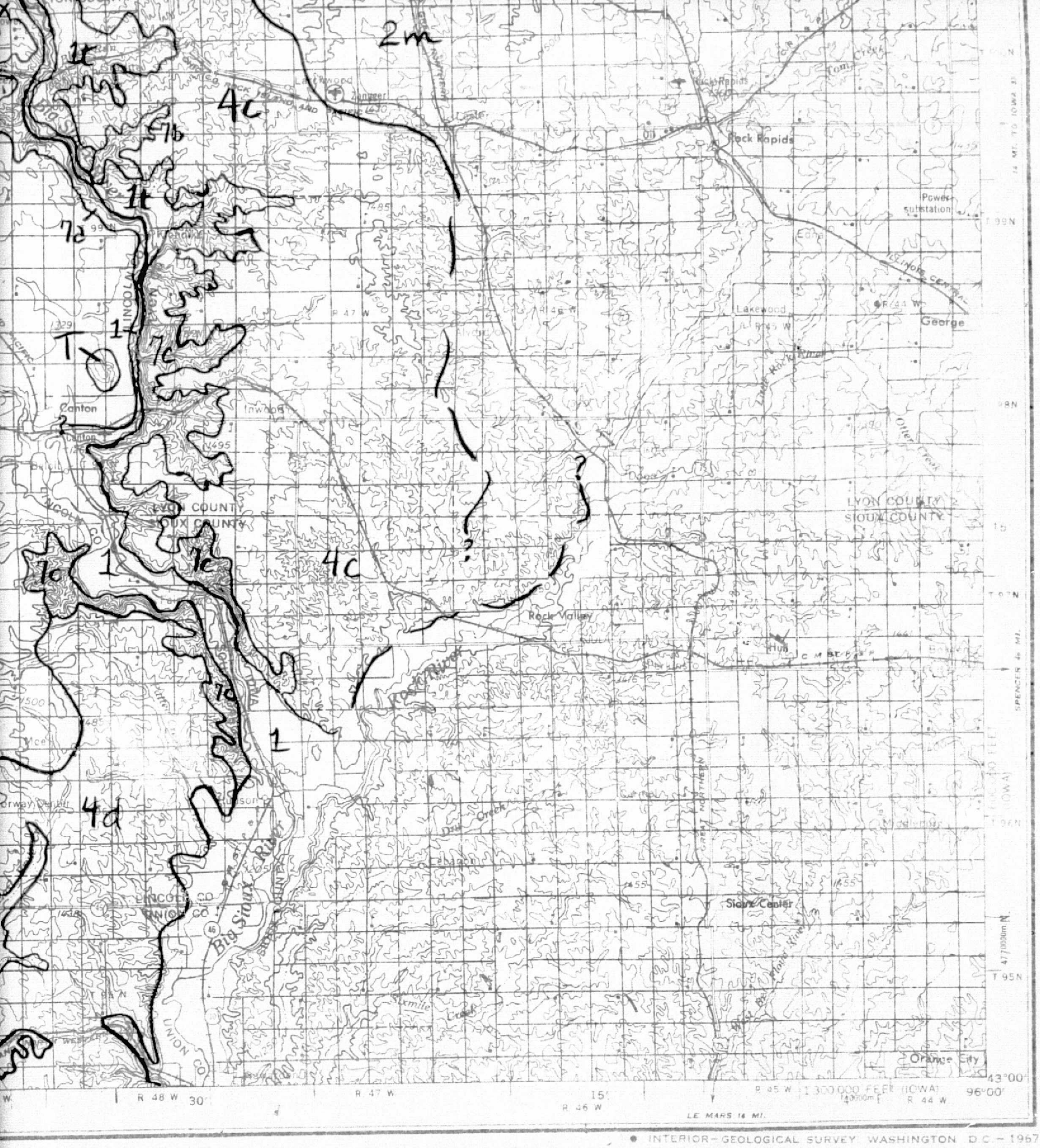
TOWNSHIP OR RANGE LINE

LAND GRANT BOUNDARY

FOLDOUT FRAME 6

0242

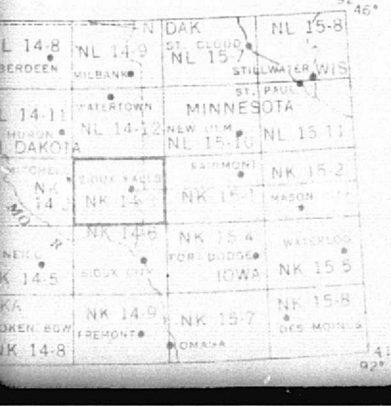
SIOUX FALLS, SOUTH DAKOTA



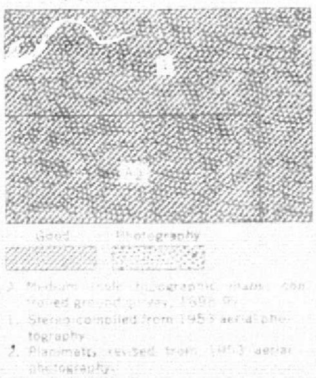
INTERIOR—GEOLOGICAL SURVEY WASHINGTON D.C.—1967

SPECIAL PRINTING
Contours and woodland symbols omitted

LOCATION DIAGRAM



RELIABILITY DIAGRAM



TOWNSHIP OR RANGE LINE
LAND GRANT BOUNDARY

SECTIONIZED TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

FOLDOUT FRAME 2

SIOUX FALLS, SOUTH DAKOTA, IOWA, MINNESOTA

FOLDOUT FRAME 1

ORIGINAL PAGE IS
OF POOR QUALITY

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Figu

MAP UNITS	ATTRIBUTES IDENTIFIABLE ON SKYLAB PHOTOGRAPHS							SURFICIAL-GEOLOGIC DEPOSITS	ENVIR		
	LANDFORM CHARACTERISTICS					SOIL CHARACTERISTICS					
			Stream dissection								
	Land-surface form symbols	Local relief (meters)	Density	Pattern	Interfluves	Surface Color	Soil Drainage		Topographic limitations	Shallow ground water availability	Gravel availability/ quality
1	Ala, V, Vf	<10	--	NA	--	Dark	Poor-fair	Alluvial clay, silt, sand, gravel	3	3	2, 3
1o	Ala, V, Vf	<10	Low	NA	--	Dark	Poor-fair	Alluvial sand and gravel, some silt	3	3	3
1t	At, Ala, Alb	<20	--	NA	--	Medium	Fair-very good	Alluvial sand and gravel, some silt	3	3	3
2g	Ala, Alb, Bla, Blb	<30	Low	Deranged	Wide, flat	Dark	Very poor-fair	Ground moraine. Clayey till--unsorted clay, silt, sand, gravel, and boulders	3	1-3	1, 2
2s	B2b, Clb, C2b	15-30	Low	Do.	Very wide, irregular topography	Dark w/ light mottles	Very poor-very good	Stagnation moraine. Clayey till--unsorted clay, silt, sand, gravel, and boulders	2, 3	1-3	1, 2
2e	Clc, C2c	15-30	Low	Do.	Rounded	Medium w/ light mottles	Fair-very good	End moraine. Unsorted clay, silt, sand, gravel, boulders	2, 3	1-3	1, 2
2m	Ala	<20	Medium	Dendritic	Flat	Dark	Fair-very good	Loess, commonly several m thick, over somewhat leached till like above	3	1-3	1, 2
3c	Clc, C2c	<30	Medium	Trellis	Rounded	Dark-medium	Poor-good	Unsorted clay, silt, gravel, boulders	2	2	2
4ce	C3c, C3d, D2d, D3d	30-60	Medium	Trellis	Some rounded, some flat	Medium-light w/ light mottles	Fair-very good	Unsorted clay, silt, sand, gravel, boulders	1	1, 2	1, 2
4cl	C2c	20-45	High	Pseudo-rectangular	Many flat-topped, rounded edges	Light	Fair-excellent	Loess, commonly several m thick, over weathered and leached clayey till	1, 2	1, 2	1
4d	C2d	20-45	Medium	Deranged	Rounded	Medium	Fair-excellent	Do.	1, 2	1, 2	1
4dl	C2d	20-45	High	Pseudo-rectangular	Some flat-topped ridges	Very light	Do.	Do.	1, 2	1, 2	1
7a	Blc, Cld, Dlc, Dld, Dle	<30	Very high (gullied)	Semi-parallel	Few to no gently sloping interfluves	Dark	Excellent	Variable	1	1	1
7b	C2d, D2c, D2d, D2e	30-60	Do.	Do.	Do.	Medium	Do.	Variable, commonly like 4cl; bedrock exposed locally	1	1	1
7c	D3c, D3d, D3e, D4e	>60	Do.	Do.	Do.	Medium	Do.	Do.	1	1	1
T	C2c, C2d	15-45	Low	Radial	--	Medium-light	Excellent	Kame--sand, gravel, boulders	1	3	[illegible]

Special Symbols

U = Urbanized (built-up area)
M = Quarry
W = Lake or pond

FOLDOUT FRAME 2

Figures A3.4, A3.5, and A3.6. Explanation for analytic geomorphology maps of the Sioux Falls, S. D., study area.

ENVIRONMENTAL-GEOMORPHIC/GEOLOGIC LIMITATIONS (Rating system: 1=severe limitations; 2=moderate limitations; 3=few limitations.)

			Construction				Drainage			Waste Disposal			
...ound ...ability	Gravel availability/ quality	Rock availability/ quality	Slope stability	Foundations	Ease of excavation	Roads	Surface	Soil (internal)	Erodibility	Sanitary landfills	Sewage lagoons	Septic tanks	Special p... or attr...
	2, 3	1	1, 2	1, 2	3	3	1, 2	1, 2	1, 2	1-3	1-3	1-3	Commonly subjec... near streams; h... table in many p...
	3	1	1, 2	2, 3	3	3	3	3	2, 3	1, 2	1, 2	3	Do.
	3	1	1, 2	2, 3	3	3	3	3	2, 3	1, 2	1, 2	3	
	1, 2	1	2	1-3	3	3	1, 2	1, 2	2, 3	2, 3	2, 3	1, 2	Poorly drained ... places.
	1, 2	1	2	1-3	3	3	1-3	1, 2	2, 3	2, 3	2, 3	1, 2	Do.
	1, 2	1	2	1-3	3	2, 3	3	1, 2	1, 2	2, 3	2, 3	1, 2	
	1, 2	1	2	2	3	3	2, 3	1, 2	2, 3	2, 3	2, 3	1, 2	
	2	1	2	2, 3	3	2	3	1, 2	2	2, 3	2, 3	1, 2	
2	1, 2	1	2	2, 3	3	1	3	1, 2	1, 2	2, 3	2, 3	1, 2	
2	1	1	2	2, 3	3	2, 3	3	1, 2	1, 2	2	2	2, 3	
2	1	1	2	2, 3	3	2, 3	3	1, 2	1, 2	2	2	2, 3	
2	1	1	2	2, 3	3	2, 3	3	1, 2	1, 2	2	2	2, 3	
	1	1	2, 3	2, 3		1	3	2, 3	1	2	2	2	
	1	3	2, 3	2, 3	1-3	1	3	2, 3	1	2	2	2	
	1	3	2, 3	2, 3	1-3	1	3	2, 3	1	2	2	2	
	3	1	1, 2	2, 3	3	1	3	3	2	1	1	3	Good source of ...

Sioux Falls, S. D., study area.

Explanation for Figs. 3.4, A3.5, and A3.6.

FOLDOUT FRAME 3

ns; 2=moderate limitations; 3=few limitations.)

nage		Waste Disposal				
Soil (internal)	Erodibility	Sanitary landfills	Sewage lagoons	Septic tanks	Special problems or attributes	Remarks
1, 2	1, 2	1-3	1-3	1-3	Commonly subject to flooding near streams; high water table in many places.	Young valley lowlands--flood plains and lower stream terraces of Holocene and in places of Wisconsinan age.
3	2, 3	1, 2	1, 2	3	Do.	Glacial outwash terraces, channels, and plains of late Wisconsinan age.
3	2, 3	1, 2	1, 2	3		Stream terraces, mainly of Wisconsinan age.
1, 2	2, 3	2, 3	2, 3	1, 2	Poorly drained depressions in places.	Ground moraine of late Wisconsinan age. Nearly level to gently rolling plains, some poorly drained depressions, marshes, ponds, and lakes.
1, 2	2, 3	2, 3	2, 3	1, 2	Do.	Stagnation moraines of late Wisconsinan age. Gently rolling plains; many poorly drained depressions, marshes, ponds, and lakes.
1, 2	1, 2	2, 3	[illegible]	1, 2		End moraines of late Wisconsinan age. Low ridges, mostly gently sloping, in places discontinuous.
1, 2	2, 3	2, 3	2, 3	1, 2		Gently rolling drift plain of early Wisconsinan age covered with late Wisconsinan loess; drainage generally well integrated.
1, 2	2	2, 3	2, 3	1, 2		Topographically similar to Illinoian drift plain (4cl) but much darker toned and slightly subdued relief.
1, 2	1, 2	2, 3	2, 3	1, 2		Highest end moraines of late Wisconsinan age (surrounding Turkey Ridge).
1, 2	1, 2	2	2	2, 3		Illinoian drift plain. Weathered clayey till mantled generally with several m of late Wisconsinan loess. Well dissected upland plain.
1, 2	1, 2	2	2	2, 3		
1, 2	I, 2	2	2	2, 3		
2, 3	1	2	2	2		Bluffs. Units 7b and 7c generally have, at top, several meters of loess over weathered clayey till of Illinoian age over Sioux Quartzite (exposed locally).
2, 3	1	2	2	2		
2, 3	1	2	2	2		
3	2	1	1	3	Good source of sand and gravel.	Glacial kames (gravelly hills).

A4.0 NORTHEASTERN NEBRASKA-WESTERN IOWA STUDY AREA

A4.1 Geomorphic setting

The northeastern Nebraska-western Iowa study area consists of two primary landscape units: on the east, an ancient drift plain, glaciated repeatedly in early and middle Pleistocene time, and subsequently mantled with loess and related deposits (commonly 2 to >30 m thick) and also considerably dissected by streams. Some of the higher stream divides appear to be remnants of end moraines of the former glaciers. On the west, beyond the glacial limit, are loess-mantled plains that grade westward into the eastern fringe of the Nebraska Sand Hills. Summit elevations of the loess plains are at different altitudes, possibly because of Quaternary tectonism. The higher plains tend to be much dissected, although gently sloping to nearly level interfluves and summit plateaus are preserved in many places (the larger ones are shown as unit 2 on the analytic geomorphology maps); they appear to be remnants of ancient loess-depositional surfaces of low relief.

Comparatively young wind-erosion features range from deflation hollows and plains (near the Sand Hills) to parallel deflation furrows that trend northwest-southeast. The latter are conspicuous on SL photos in some places east of the Sand Hills, particularly in the northwestern part of the main part of the study area (Fig. A4.3).

A4.2 Useful coverage

The only coverage of the western part of the study area, in the Broken Bow $1^{o} \times 2^{o}$ quadrangle, that is stereoscopic, relatively cloud-free, and of fairly good photo quality is by SL4 Pass 83 (Track 30) S190B (frames 93-095 to 93-097). These photos are somewhat overexposed but were used to prepare Fig. A4.2. (The S190A photos from this flight are so badly overexposed as to be unusable.)

The eastern part of the study area has high-quality coverage by both S190B and S190A photos from SL2 Pass 6 (Track 19); also the northwestern part of its northern half (parallel with the SL2 Pass 6 coverage) is covered by cloud-free photos from SL4 Pass 85 (Track 19, 1-18-74). The SL3 Pass 27 (Track 30/44) flight crossed the area from southwest to northeast, but the photos were taken at the height of the growing season and have only 10-15% overlap (hence are non-stereoscopic), so are much less useful than the others.

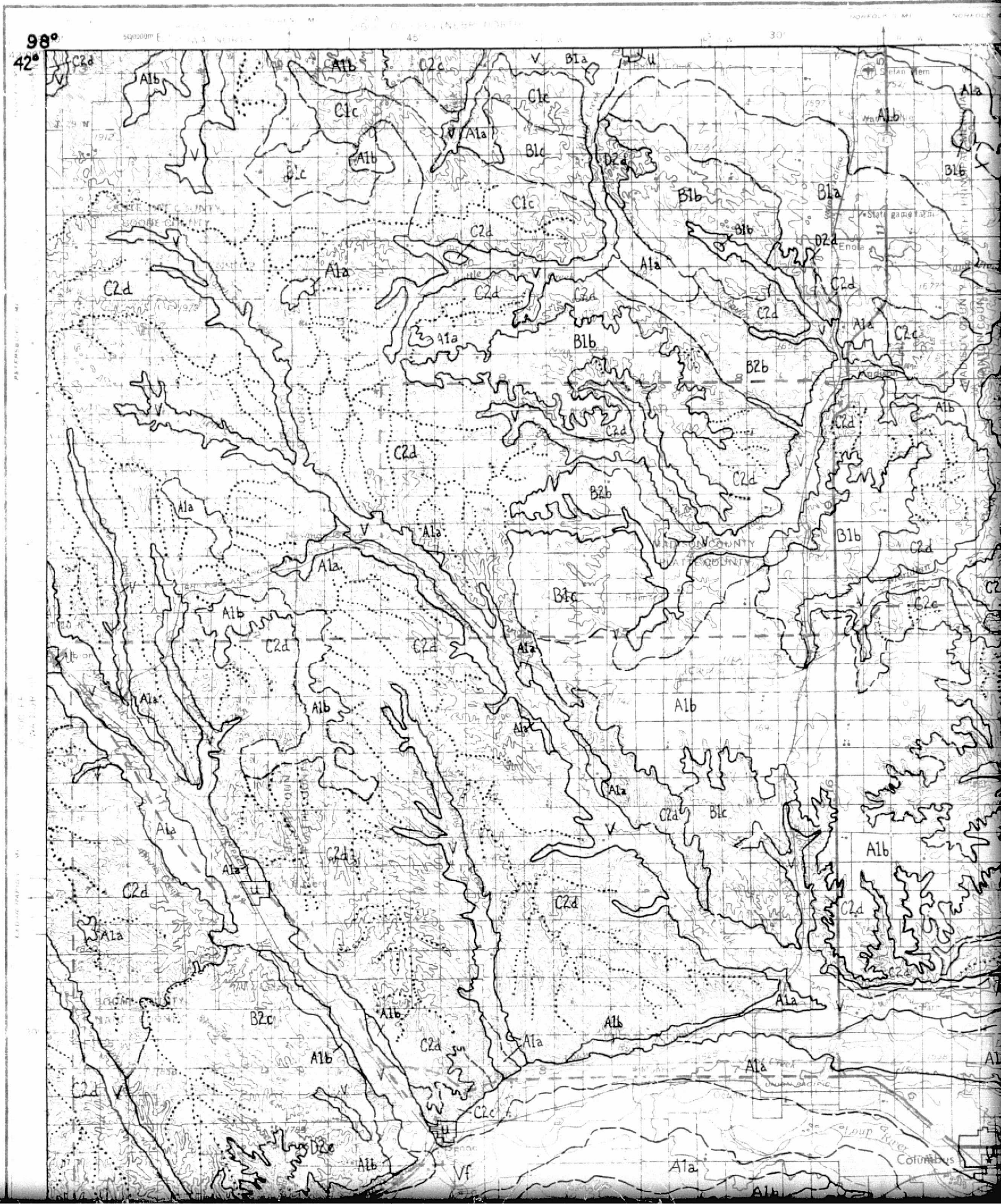
A4.3 Interpretive procedure and results

A land-surface form map (Fig. A4.1) of the Fremont $1^{o} \times 2^{o}$ quadrangle was first prepared from $7\frac{1}{2}$-minute topographic quadrangles by the method described in section 7.7, to serve as a convenient basis for evaluating the results from interpreting SL photos to map the geomorphology of part of this quadrangle, as discussed in connection with Figures A4.3a and A4.3b.

Figure A4.1 near here

OF POOR QUALITY

Figure A4.1.



FOLDOUT FRAME 2

FOLDOUT

FREMONT

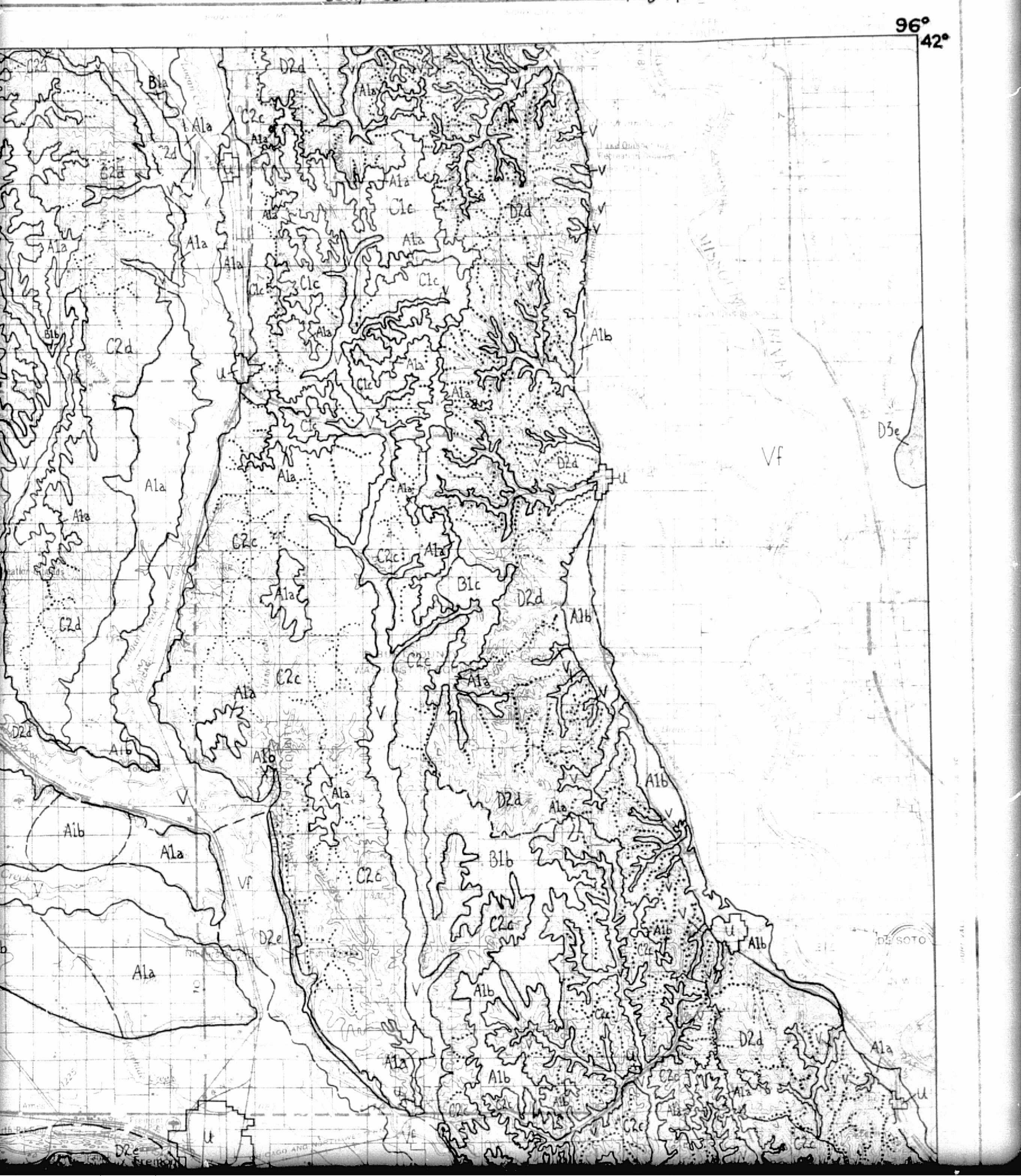
FOLDOUT FRAME 3

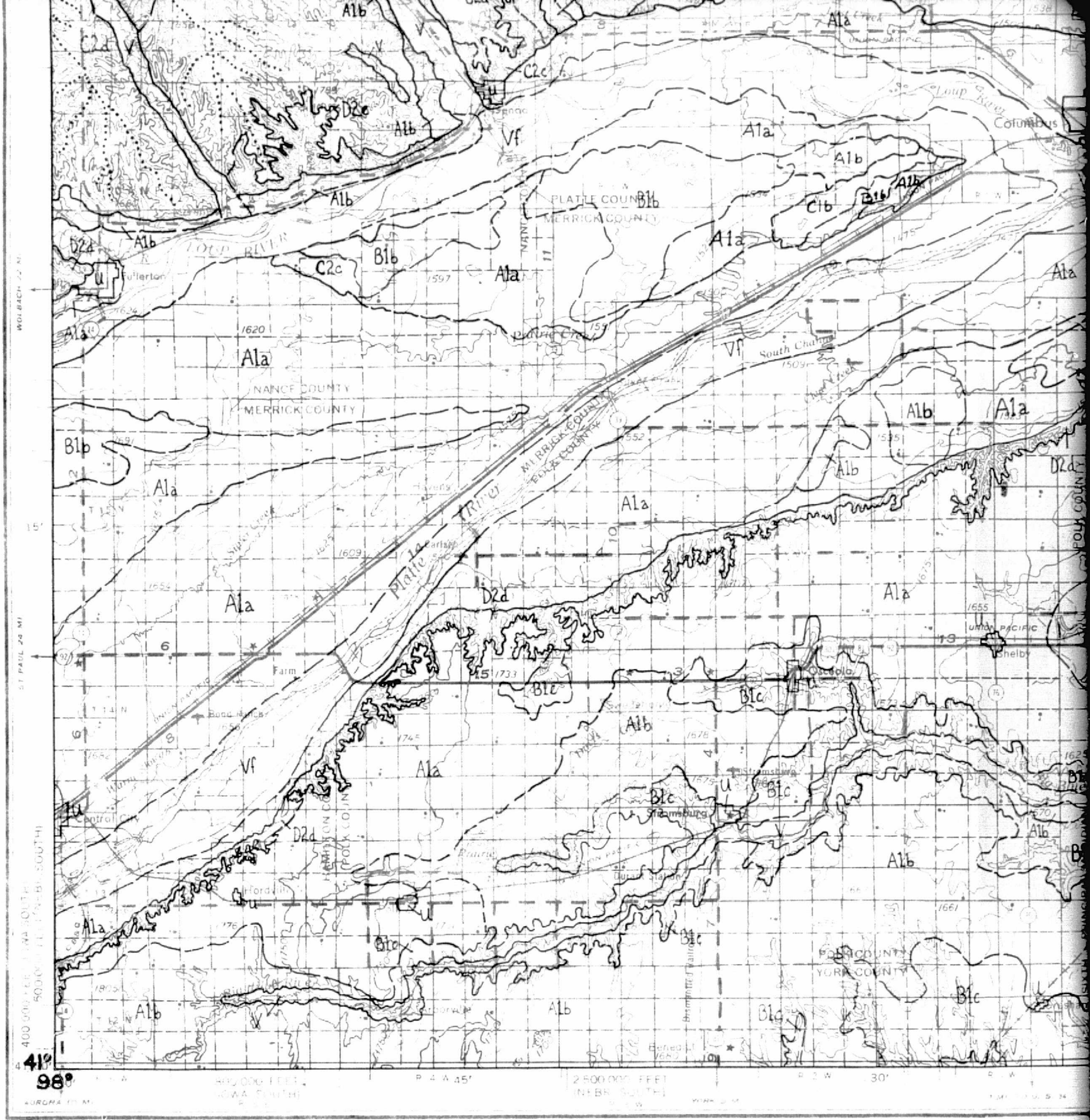
Land surface form map o

compiled from 7½-minute topographic

FOLDOUT FRAME 5

Land surface form map of the Fremont 1° x 2° quadrangle compiled from 7½-minute topographic quadrangle maps





Prepared by the Army Map Service (ASTT), Corps of Engineers, U.S. Army, Washington, D.C. Compiled in 1955 by photogrammetric methods. Horizontal and vertical control by USGS, USC&GS and USCE. Aerial photography 1953. Photography field annotated 1955. Limited revision by U.S. Geological Survey 1966.

100,000-foot grids based on Nebraska coordinate system, south and north zones, and Iowa coordinate system, south and north zones.

10,000-meter Universal Transverse Mercator grid ticks, zone 14, shown in blue.

LEGEND

ROAD DATA 1955 — PARTIALLY REVISED 1966

Figures in red denote approximate distances in miles between stars

POPULATED PLACES

Over 500,000 — LOS ANGELES
100,000 to 500,000 — OMAHA
25,000 to 100,000 — GALVESTON
5,000 to 25,000 — Laramie
1,000 to 5,000 — Grand Coulee
Less than 1,000 — Sun Valley

ROADS
Hard surface, heavy duty
More than two lanes wide
Two lanes wide; Federal route marker
Hard surface, medium duty
More than two lanes wide
Two lanes wide; State, Interstate route marker
Improved light duty
Unimproved dirt
Trail

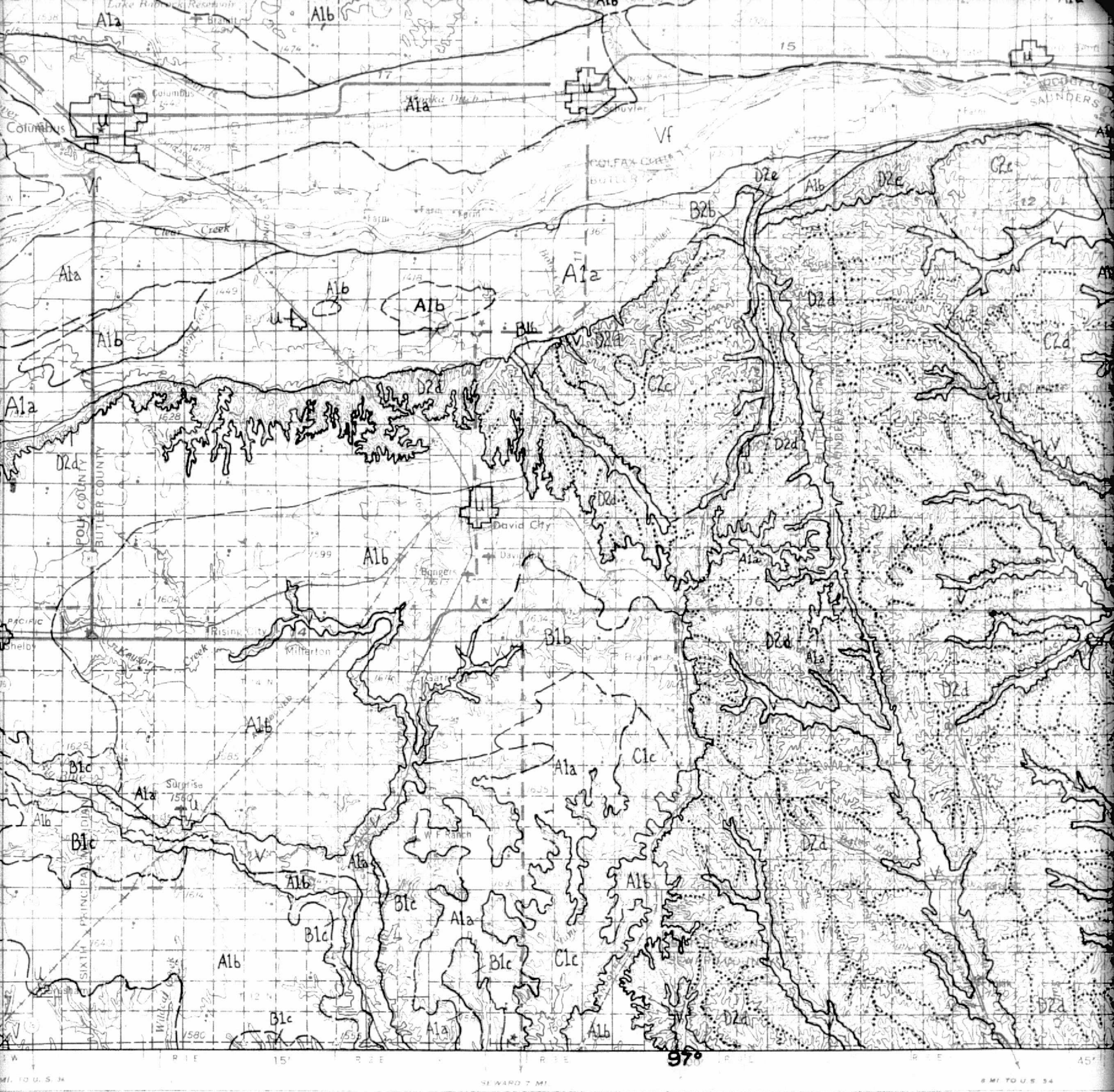
RAILROADS
Single track / Double or multiple
Standard gauge
Narrow gauge

BOUNDARIES
International
State
County
Park or reservation

Landplane airport
Landing area
Seaplane airport
Seaplane anchorage
Woods-brushwood

Landmarks: School; Church
Horizontal control point
Spot elevation in feet
Marsh or swamp
Intermittent or dry stream
Power line

FOLDOUT FRAME 5



Scale 1:250,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilometers

5 0 5 10 15 Nautical Miles

CONTOUR INTERVAL 50 FEET
WITH SUPPLEMENTARY CONTOURS AT 25 FOOT INTERVALS

TRANSVERSE MERCATOR PROJECTION

1965 MAGNETIC DECLINATION FROM TRUE NORTH FOR THIS SHEET VARIES FROM 9½° (170 MILS) EASTERLY FOR THE CENTER OF THE WEST EDGE TO 8½° (150 MILS) EASTERLY FOR THE CENTER OF THE EAST EDGE.

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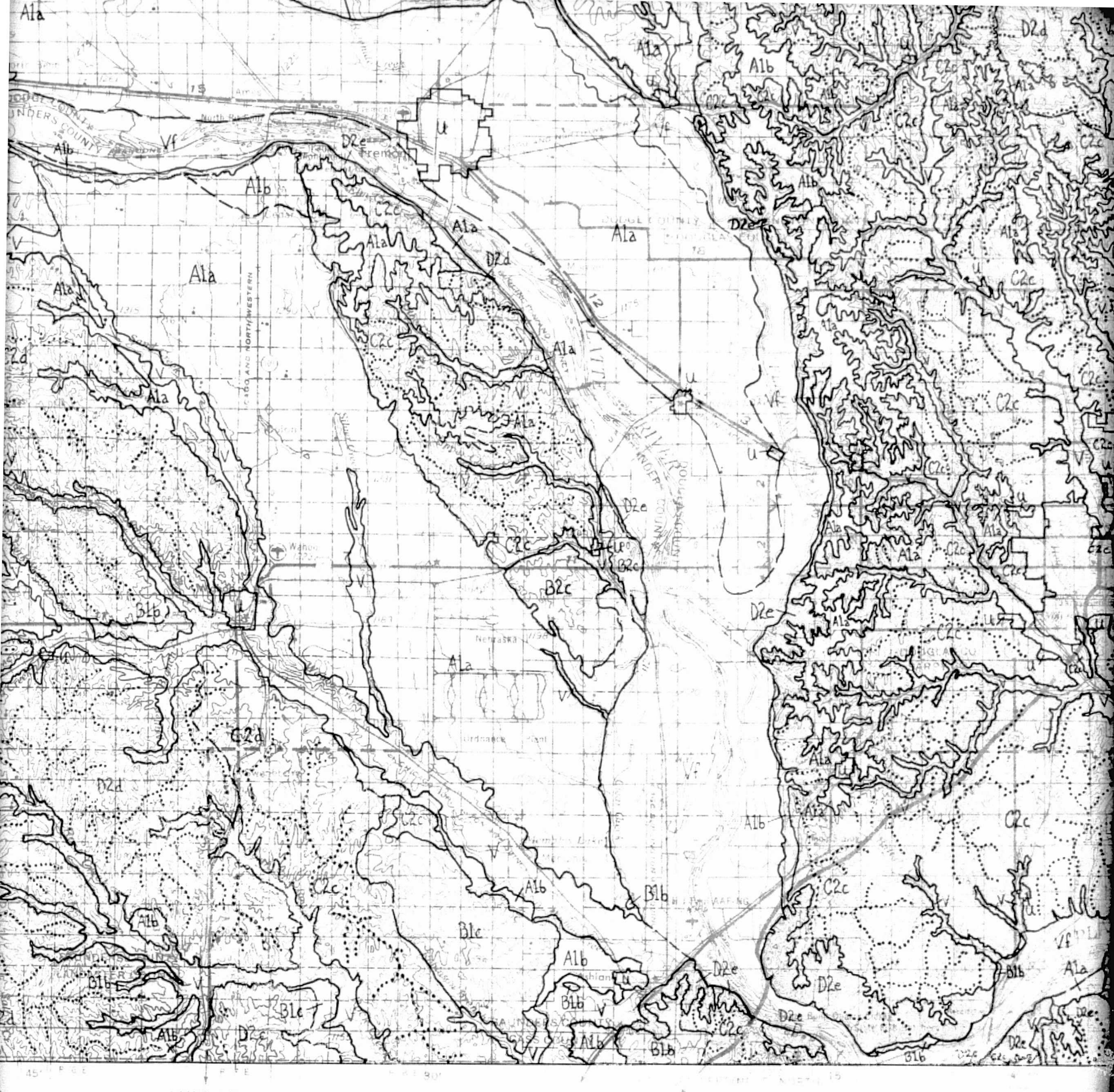
stars

3 LANES | 4 LANES
route marker
3 LANES | 4 LANES
erstate route markers
marks: School, Church, Other
ontal control point
elevation in feet
or swamp
ittent or dry stream
line

FOLDOUT FRAME 6

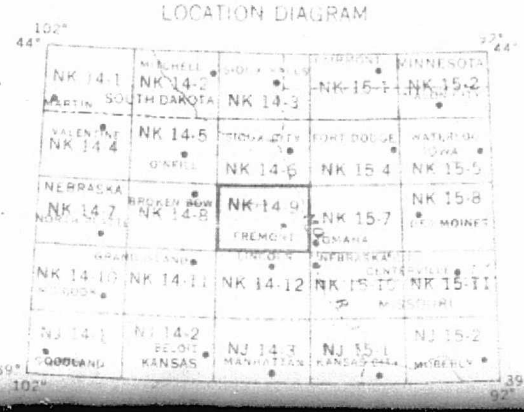


20 Statute Miles

Kilometers

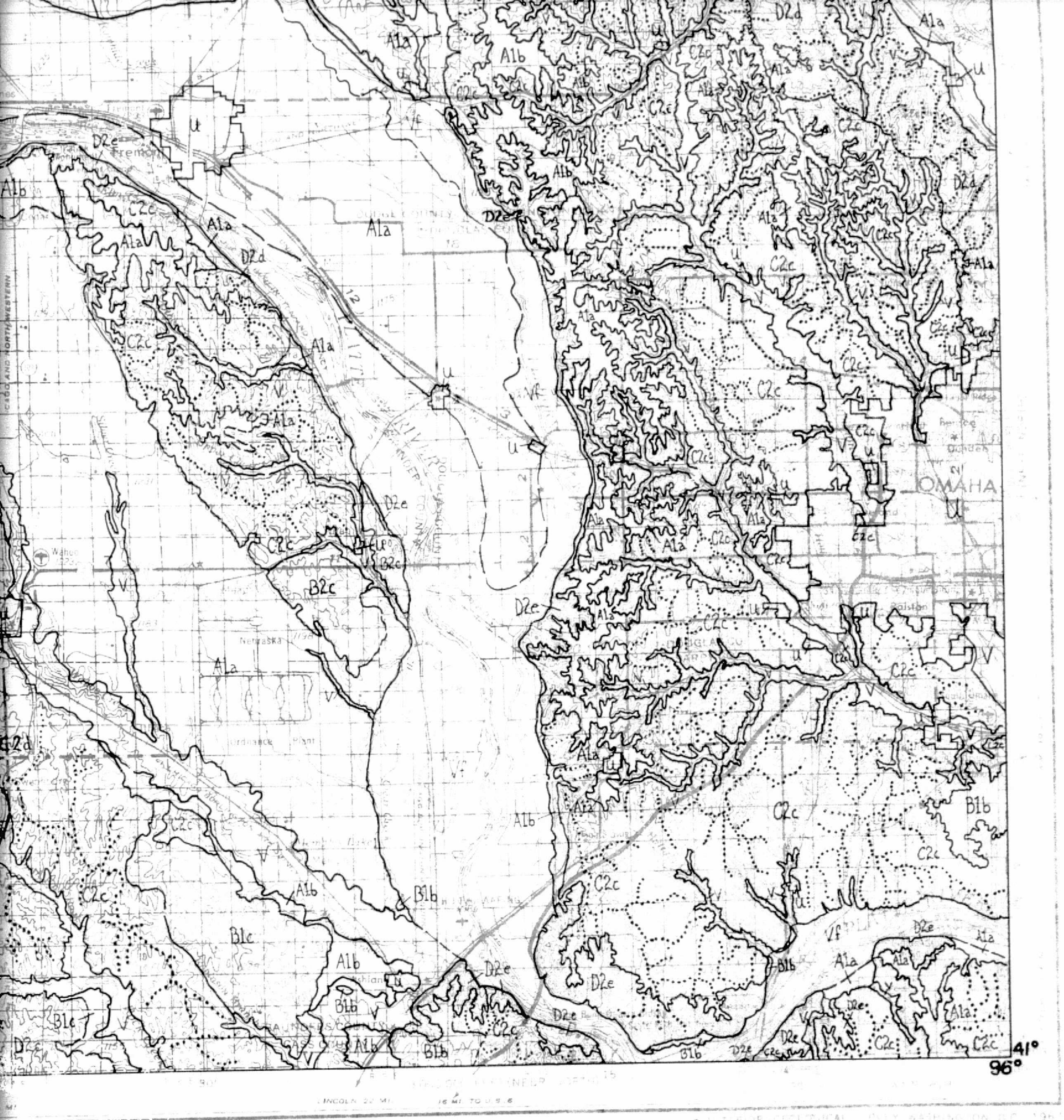
Miles

LOCATION DIAGRAM

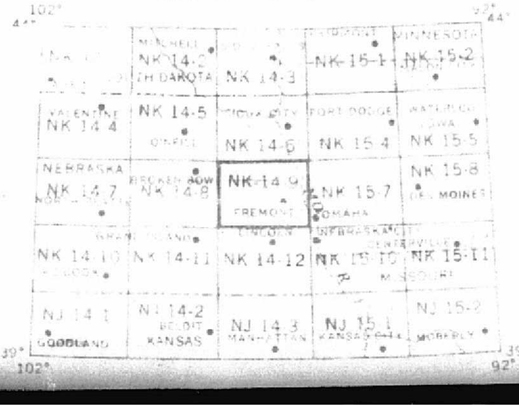


FOLDOUT FRAME 7

FOLDOUT FRAME



LOCATION DIAGRAM



FOLDOUT FRAME 8

FREMONT, NEBRASKA, IOWA

This study area (and some adjoining areas) was used as a training area for various interpreters on the project and for determining the most feasible methods of mapping and map-unit classification. All the methods discussed in section 7.3 were used, and photos from all SL flights and bands over the area were examined. We prepared analytic geomorphology maps of most of the Fremont and Sioux City $1^{o} \times 2^{o}$ quadrangles and of parts of the Broken Bow, Omaha, O'Neill, and Nebraska City quadrangles. These maps are not included here, partly because of space limitations and partly because much of the early interpretive mapping was relatively generalized and its detail and accuracy do not warrant reproduction at the 1:250,000 scale of the base maps we used (Figure A4.2 is an example). However, we hope later to revise and compile the information from these maps for a regional map at 1:500,000 scale, as a project under the USGS EROS Program.

Figure A4.3a is a geomorphic-map overlay to a 2 X color enlargement of S190B frame 81-170 from SL2 Pass 6 (Track 19), covering the vicinity of Omaha, Nebraska. It was prepared by viewing adjoining S190B stereopairs from this flight through an Old Delft scanning stereoscope under 4.5 X magnification. It illustrates the basis of the strip map (Fig. A4.3b) that combines the results from analysis of five S190B frames from this flight (shown at the scale of the 2 X enlargements).

The analytic geomorphology map of part of the Broken Bow $1^{o} \times 2^{o}$ quadrangle was prepared entirely by viewing and interpretation in a single process using a Kern PG-2 stereoplotter (Fig. A4.4). It was made to test the feasibility of relatively detailed geomorphic mapping from somewhat overexposed S190B color photos (unenlarged) of entirely snow-covered terrain. In spite of the overexposure of the photos and relatively high sun-elevation angle, the chief terrain details could be distinguished--commonly more successfully than with snow-free photos (on snow-free photos, distracting noise from land-use patterns commonly hinders geomorphic interpretation). Because of the washed-out character of the SL4 photos, their illumination in the Kern plotter had to be reduced to the minimum possible.

Figure A4.2--NEAR HERE

Figure A4.3a--NEAR HERE
A4.3b--NEAR HERE

Figure A4.4-NEAR HERE

Figure A4.2. Preliminary geomorphic map of the Fremont 1° × 2° quadrangle.

Figure A4.2.

ANALYTIC GEOMORPHOLOGY MAP

EXPLANATION

Valley lowlands (flood plains and low stream terraces)

Undifferentiated valley lowlands

Holocene flood plains

Lowest terraces of Wisconsinan age

Upper terraces of Wisconsinan age

Sand dunes, undifferentiated

Loess-mantled plains beyond the glacial limit

Loess plains, flat to gently sloping, without appreciably entrenched stream valleys; local relief 75 - 150 ft (23 - 45 meters).

Loess plains, slightly dissected with wide, flat to gently sloping interfluves and few, widely spaced valleys; local relief 75-150 ft (23-45 meters).

Loess plains, moderately dissected with many gently sloping interfluves and many valleys; local relief 75 - 150 ft (23 - 45 meters).

Loess plains, moderately dissected, with few to many gently sloping interfluves; local relief 150 - 225 ft (45 - 68 meters).

Glacial-drift plains of middle Pleistocene age

Drift plains with loess mantle of variable thickness, moderately dissected with many gently sloping interfluves; local relief 75 - 150 ft (23 - 45 m).

Like above but local relief 150 - 225 ft (45 - 68 meters).

Bluffs, highly dissected, no gently sloping interfluves; local relief 75 - 350 ft (23 - 105 meters).

Urban areas

Main geologic linears

gure A4.3a. Analytic geomorphology of parts of the Fremont and Omaha 1° x 2° quadrangle
braska-Iowa. Overlay to 2 X enlargement of SL2 Pass 6 S190B color frame 81-170.

MAP UNITS	ATTRIBUTES IDENTIFIABLE ON SKYLAB PHOTOGRAPHS							SURFICIAL-GEOLOGIC DEPOSITS	ENV		
	LANDFORM CHARACTERISTICS					SOIL CHARACTERISTICS					
			Stream dissection								
	Land-surface form symbol(s)	Local relief (meters)	Density	Pattern	Interfluves	Surface Color	Soil Drainage		Topographic limitations	Shallow ground water availability	Gravel availabili[ty] quality
1	Ala	< 15	---	---	---	Light-dark	Poor to good	Alluvial silt, clay, sand, gravel	3	3	2,3
1f	Ala	< 5	---	---	---	Medium-dark	Fair to poor	Do.	3	3	2,3
1t	Ala, Alb, Bla	< 15	---	---	---	Light medium	Fair to good	Do.	3	2,3	3
21	Ala, Alb	Generally < 15	Sparse	Dendritic	Very wide, gently sloping to nearly level	Mostly light, in places medium to dark	Poor to good	Late Wisconsinan loess, locally over older loess, and in places east of Columbus-Norfolk, over glacial drift	3	1,2	1
31	Bla, Blb	Generally < 20	Sparse-medium	Do.	Rounded to flat	Mostly light	Fair to good	Do.	2,3	2	1
4c1	Clc	Generally < 30	Medium	Do.	Many flattish interfluves	Light-medium	Good	Do.	2	1,2	1
4d1	Cld, Dld	Generally < 30	Fairly high	Do.	Some flattish interfluves	Do.	Good	Do.	1,2	1,2	1
5c1	C2c, D2c	30-60	Do.	Do.	Many flattish interfluves	Do.	Good	Do.	1,2	1,2	1
5d1	C2d, D2d	30-60	High	Do.	Some flattish interfluves	Do.	Good	Do.	1,2	1,2	1
5e1	D2e	30-60	High	Do.	Few flattish interfluves	Do.	Good	Do.	1,2	1,2	1
6c1	D3c	> 60	High	Dendritic	Many flattish interfluves	Medium-light	Fair to good	Late Wisconsinan loess, commonly over older loess, and in places over glacial drift.	1,2	2	1,2
6d1	D3d	> 60	High	Do.	Some flattish interfluves	Do.	Good	Do.	1,2	2	1,2
6e1	D3e	> 60	High	Do.	Few or no flattish interfluves	Do.	Do.	Do.	1,2	2	1,2
7a	Clc	< 30	High	---	Do.	Do.	Do.	Do.	1	1	1
7b	C2c, C2d, D2c, D2d	30-60	Very high	---	Do.	Do.	Do.	Do.	1	1	1
7c	C3d, D3d, D3e	> 30	Very high	---	Do.	Do.	Do.	Do.	1	1	1
8u	Blb, B2b, Clb, Clc	Commonly > 15, generally < 30	Low	---	---	Light	Very good	Eolian sand	1,2	3	1
8m	Blb, Clb	Generally < 20	Low	---	---	Do.	Do.	Do.	2	3	1
8i		Generally < 15	Low	---	---	Do.	Do.	Do.	2,3	3	1
8id		Generally < 15	Low	---	---	Do.	Do.	Do.	2,3	3	1
8ie		Generally < 15	Low	---	---	Do.	Do.	Do.	2,3	3	1
8d		< 15	Low	---	---	Do.	Do.	Fairly continuous cover of eolian sand	3	3	1

Special symbols

U=Urbanized (built-up) areas

=geologic linear

ω =geologic linear (eolian)

FOLDOUT FRAME

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Figures A4.3a, A4.3b, and A4.4. Explanation for analytic geomorphology maps of the northeastern Nebraska study are

ENVIRONMENTAL-GEOMORPHIC/GEOLOGIC LIMITATIONS (Rating system: 1=severe limitations; 2=moderate limitations; 3=few limitations.)

Gravel availability/ quality	Rock availability/ quality	Construction				Drainage		Erodibility	Waste Disposal			Special problems or attributes
		Slope stability	Foundations	Ease of excavation	Roads	Surface	Soil (internal)		Sanitary landfills	Sewage lagoons	Septic tanks	
2,3	1	1-2	1-3	3	3	1-3	1-3	1-2	1-3	2-3	1-3	Commonly subject to fl near streams; high wat in many places.
2,3	1	1-2	1-3	3	3	1-2	1-2	1-2	1,2	2-3	1,2	Large parts are subjec flooding, except where tected by flood-contro
3	1	2,3	2,3	3	3	2-3	3	2-3	2	2	2,3	
1	1	2,3	2,3	3	3	1-3	1,2	2,3	2	2	2	
1	1	2,3	2,3	2,3	2,3	3	2,3	1,2	2	2	2	
1	1	1-3	2	3	2	3	2,3	1,2	2	2	2	
1	1	1-3	2	3	1,2	3	2,3	1	2	2	2	
1	1,2	1-3	2	3	1,2	3	2,3	1,2	2	2	2	
1	1,2	1-3	2	3	1,2	3	2,3	1	2	2	2	
1	1,2	1-3	2	3	1,2	3	2,3	1	2	2	2	
1,2	1	2	2	3	1,2	3	2	1,2	2	2	2	
1,2	1	2	2	3	1,2	3	2	1	2	2	2	
1,2	1	2	2	3	1,2	3	2	1	2	2	2	
1	1	1-3	2	2,3	1,2	3	2,3	1	1	1	1	
1	1,2	1-3	2	2,3	1	3	2,3	1	1	1	1	
1	1,2	1-3	2	2,3	1	3	2,3	1	1	1	1	
1	1	1	2	3	1,2	3	3	1	2	2	3	Poorly consolidated sand liable to wind erosion.
1	1	1	2	3	2	3	3	1	2	2	3	Do.
1	1	1	2	3	2,3	3	3	1	2	2	3	Do.
1	1	1,2	2	3	2,3	3	3	1	2	2	3	
1	1	1	2	3	2,3	3	3	1	2	2	3	
1	1	1,2	2	3	3	3	3	1,2	2	2	3	

FOLDOUT FRAME 2

northeastern Nebraska study are—

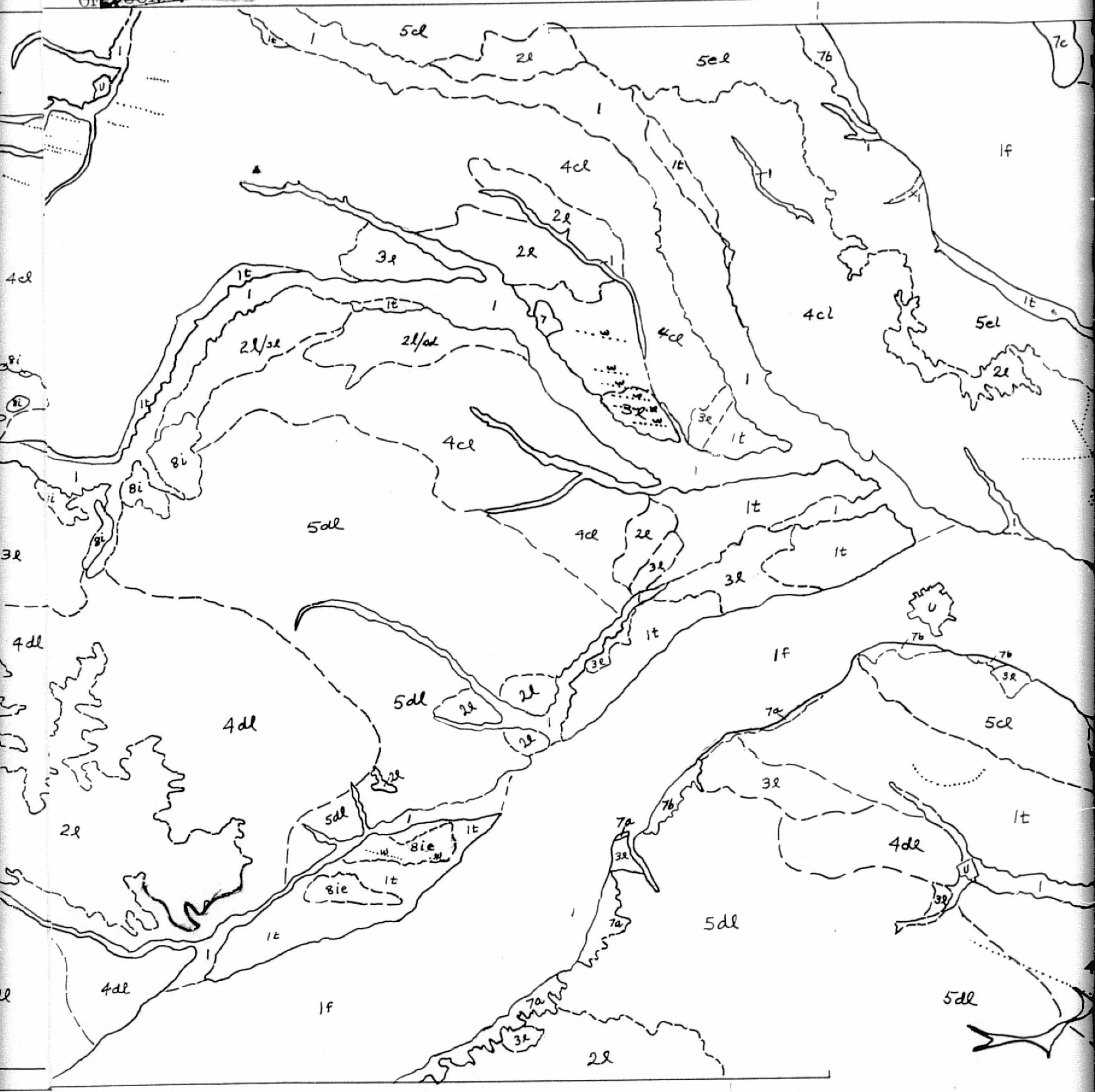
ions; 2=moderate limitations; 3=few limitations.)

ainage		Waste Disposal				
Soil (internal)	Erodibility	Sanitary landfills	Sewage lagoons	Septic tanks	Special problems or attributes	Remarks
1-3	1-2	1-3	2-3	1-3	Commonly subject to flooding near streams; high water table in many places.	Valley lowlands, undifferentiated. Flood plains of Holocene age and lower stream terraces.
1-2	1-2	1,2	2-3	1,2	Large parts are subject to flooding, except where protected by flood-control levees	Flood plains of late Holocene age (including but not restricted to modern flood plains).
3	2-3	2	2	2,3		Stream terraces, mainly of Wisconsinan age, including some glacial outwash terraces.
1,2	2,3	2	2	2		Gently undulating upland plains, underlain by loess of late Wisconsinan age, locally by older loessic deposits, and east of Columbus-Norfolk, by glacial drift of middle and early Pleistocene age.
2,3	1,2	2	2	2		Gently rolling hills, generally covered by loess, locally (east of Columbus-Norfolk) over glacial drift (middle and early Pleistocene).
2,3	1,2	2	2	2		Hilly uplands with local relief generally < 30 m, many near level to gently rolling interfluves; mantled by loess, in places (east of Columbus-Norfolk) over glacial drift (middle and early Pleistocene).
2,3	1	2	2	2		Like above, but fewer flattish interfluves.
2,3	1,2	2	2	2		Moderately deeply dissected uplands with many flattish interfluves; surficial deposits like above.
2,3	1	2	2	2		Like above; some flattish interfluves.
2,3	1	2	2	2		Like above; few to no flattish interfluves.
2	1,2	2	2	2		Deeply dissected uplands, generally mantled with late Wisconsinan loess, in places over older weathered loess, and/or glacial drift (middle and early Pleistocene).
2	1	2	2	2		Do.
2	1	2	2	2		Do.
2,3	1	1	1	1		Bluffs < 30 m high.
2,3	1	1	1	1		Bluffs 30-60 m high.
2,3	1	1	1	1		Bluffs > 60 m high.
3	1	2	2	3	Poorly consolidated sand, very liable to wind erosion.	Dune fields, mainly of U-shaped (longitudinal) dunes, commonly higher than 15 m; active dunes, and blow-outs in places
3	1	2	2	3	Do.	Dune fields with mixed low dune forms (< 20 m) partly longitudinal, partly irregular, commonly poorly developed, mostly stabilized.
3	1	2	2	3	Do.	Irregular dunes, generally < 15 m high, mostly stabilized.
3	1	2	2	3		Like above but dunes commonly indistinct and scattered on plain with discontinuous cover of eolian sand.
3	1	2	2	3		Irregular dunes, generally indistinct (eroded), < 15 m high, stabilized.
3	1,2	2	2	3		Deflation hollows and plains, commonly with scattered low dunes, generally < 15 m high.

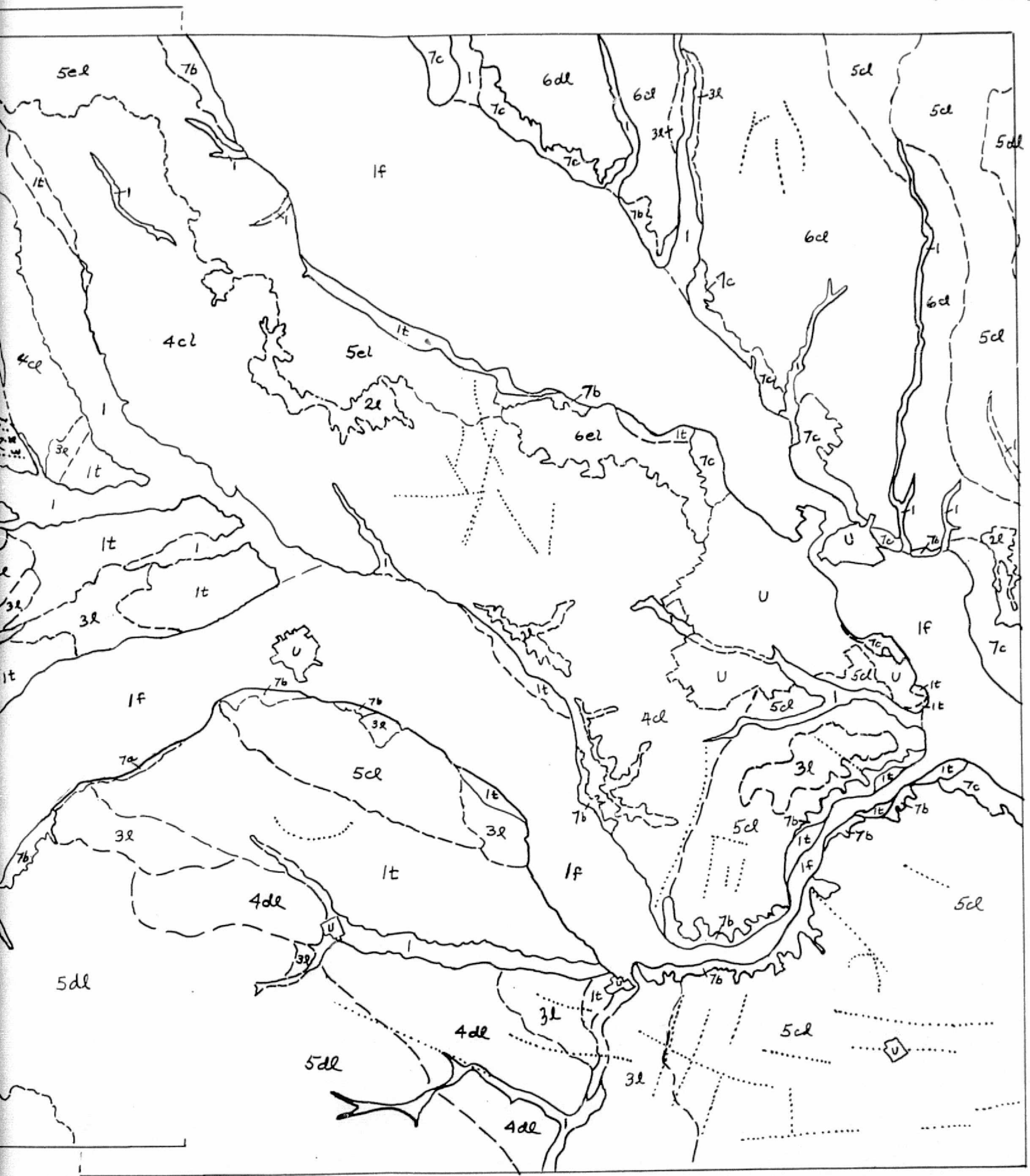
FOLDOUT FRAME 3

Figure A4.3b. Analytic geomorphology of parts of the Fremont and Omaha

FOLDOUT FRAME 2



and Omaha 1° x 2° quadrangles, Nebraska-Iowa. Overlay to 2X enlargements of SL2



erlay to 2X enlargements of SL2 Pass 6 S190 B color frames 81-170 to 81-174.

FOLDOUT FRAME 2

of the Broken Bow 1° x 2° quadrangle (scale 1:250,000), Nebraska, interp

BROKEN BOW

FOLDOUT FRAME 3

rpreted from SL4 S190 color photos (frames 93-1196 to 93-1981) (entirely

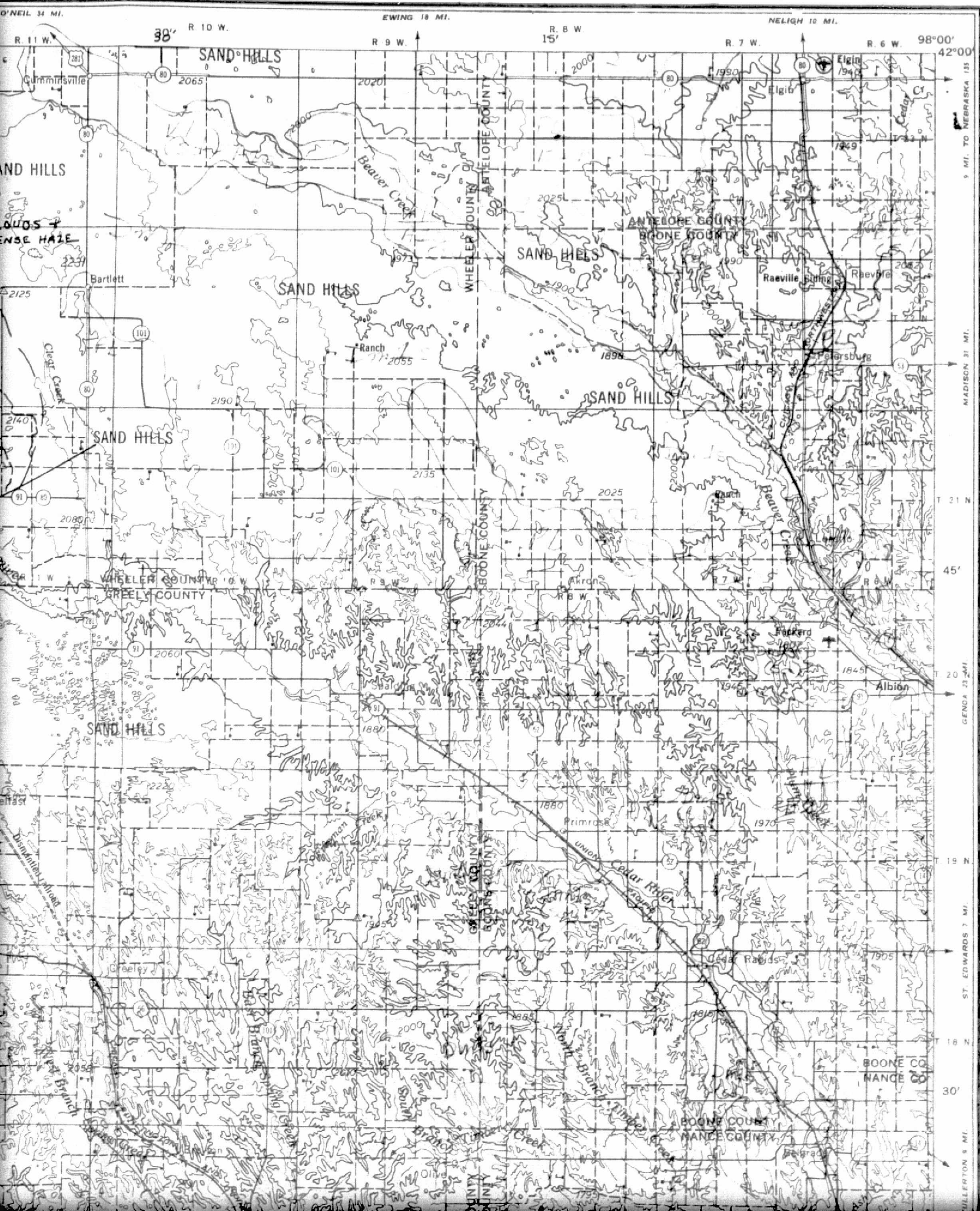
EDITION 1-AMS

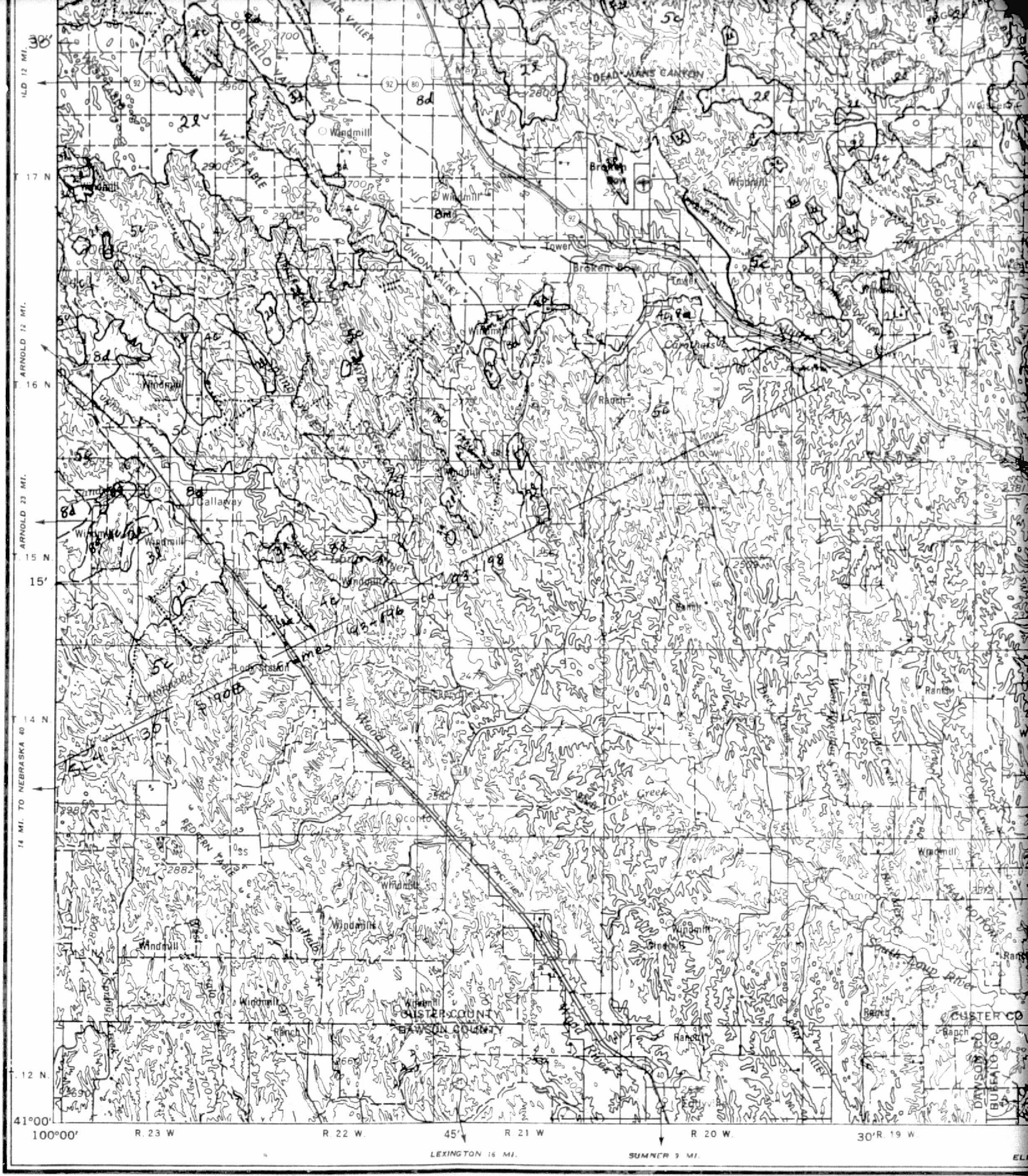
4 S190 color photos (frames 93-196 to 93-198) (entirely

FOLDOUT FRAME

EDITION 1-AMS

REFER TO THIS MAP AS: **NK 14-8**
SERIES V502





V502

Edition 1-AMS (First Printing, 9-56)

Prepared by the Army Map Service (ASSX), Corps of Engineers, U.S. Army, Washington, D.C. Compiled in 1955 by photogrammetric methods and from Nebraska quadrangles, 1:24,000, USGS, 1951, 1952 and 1954. Planimetric detail revised by photo-planimetric methods. Horizontal and vertical control by USC&GS, USGS and CE. Photography field annotated, 1954-55.

LEGEND

ROAD DATA 1955

Figures in red denote approximate distances in miles between stars

POPULATED PLACES

Over 500,000 — LOS ANGELES

100,000 to 500,000 — OMAHA

25,000 to 100,000 — GALVESTON

5,000 to 25,000 — Laramie

1,000 to 5,000 — Grand Coulee

Less than 1,000 — Sun Valley

RAILROADS

Single track | Double or Multiple

Standard gauge

Narrow gauge

BOUNDARIES

International

ROADS

Hard surface, heavy duty

More than two lanes wide

Two lanes wide; Federal route marker

Hard surface, medium duty

More than two lanes wide

Two lanes wide; State route marker

Improved light duty

Unimproved dirt

Trail

Landplane airport

Landing area

Seaplane airport

Landmarks: Scho

Horizontal contro

Spot elevation in

Marsh or swam

BROKEN BOW, NEB

FOLDOUT FRAME 5

s between stars

eavy duty
o lanes wide — 3 LANES | 4 LANES
e; Federal route marker — 151
edium duty
o lanes wide — 3 LANES | 4 LANES
e; State route marker — 10

uty
irt

Landmarks: School; Church; Other

Horizontal control point — △

Spot elevation in feet — 221

Scale 1:250,000

5 0 5 10 15

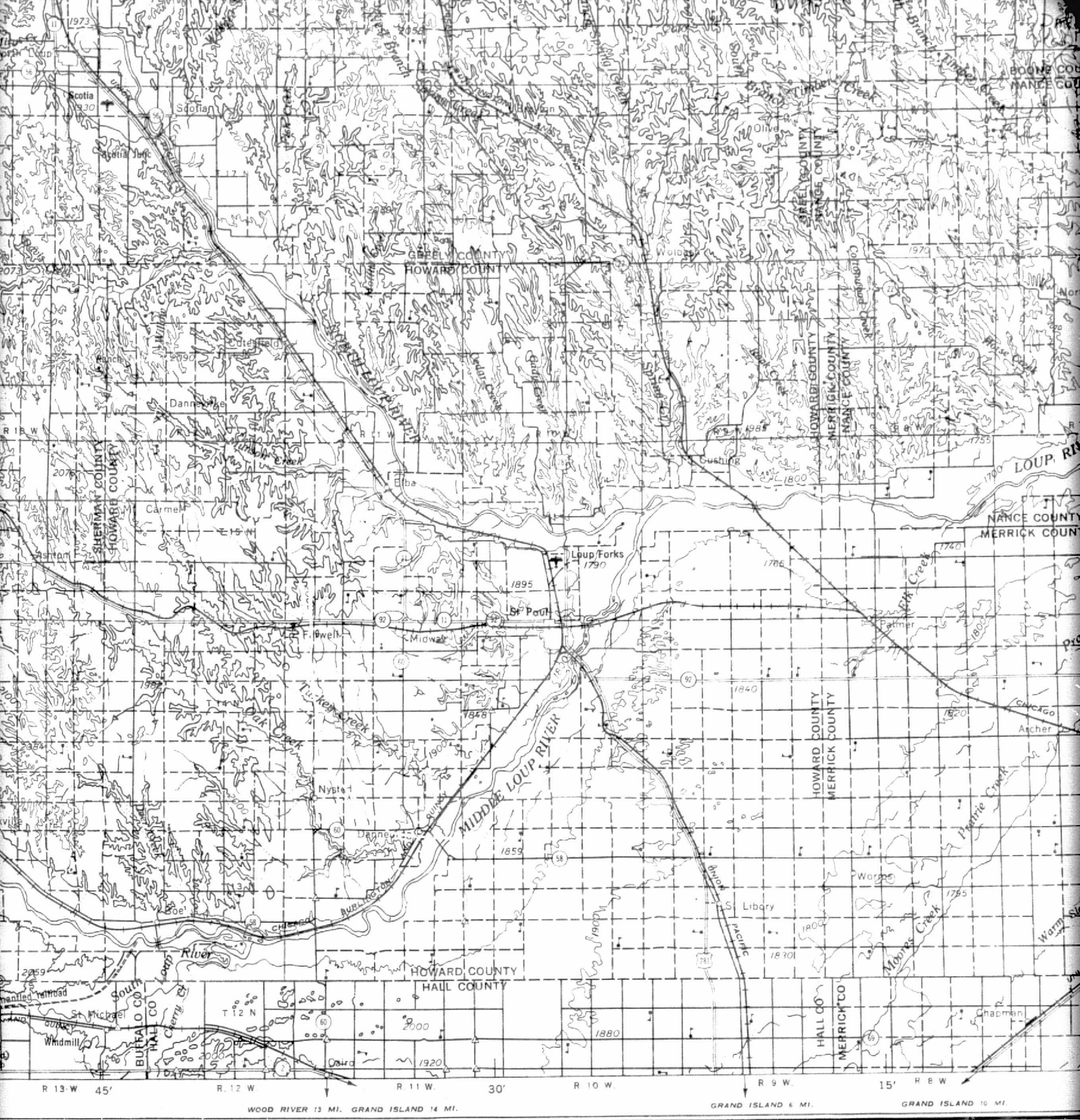
5 0 5 10 15 20 25 30

5 0 5 10 15 Nautical

FOLDOUT FRAME 6

CONTOUR INTERVAL 100 FEET

TRANSVERSE MERCATOR PROJECTION

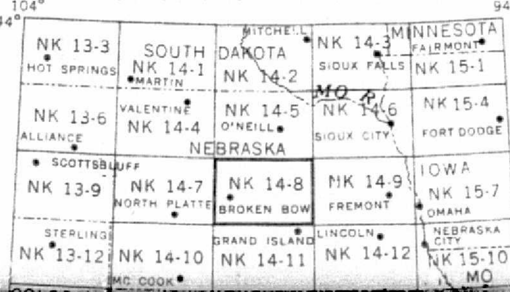


20 Statute Miles

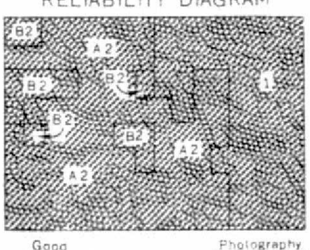
30 Kilometers

15 Nautical Miles

LOCATION DIAGRAM FOR NK 14-8



RELIABILITY DIAGRAM



Good

Photography

A. Large scale topographic maps, photogrammetric survey, 1951, 1952, 1954.
B. Large scale topographic maps, controlled ground and photogrammetric survey, 1951-52.

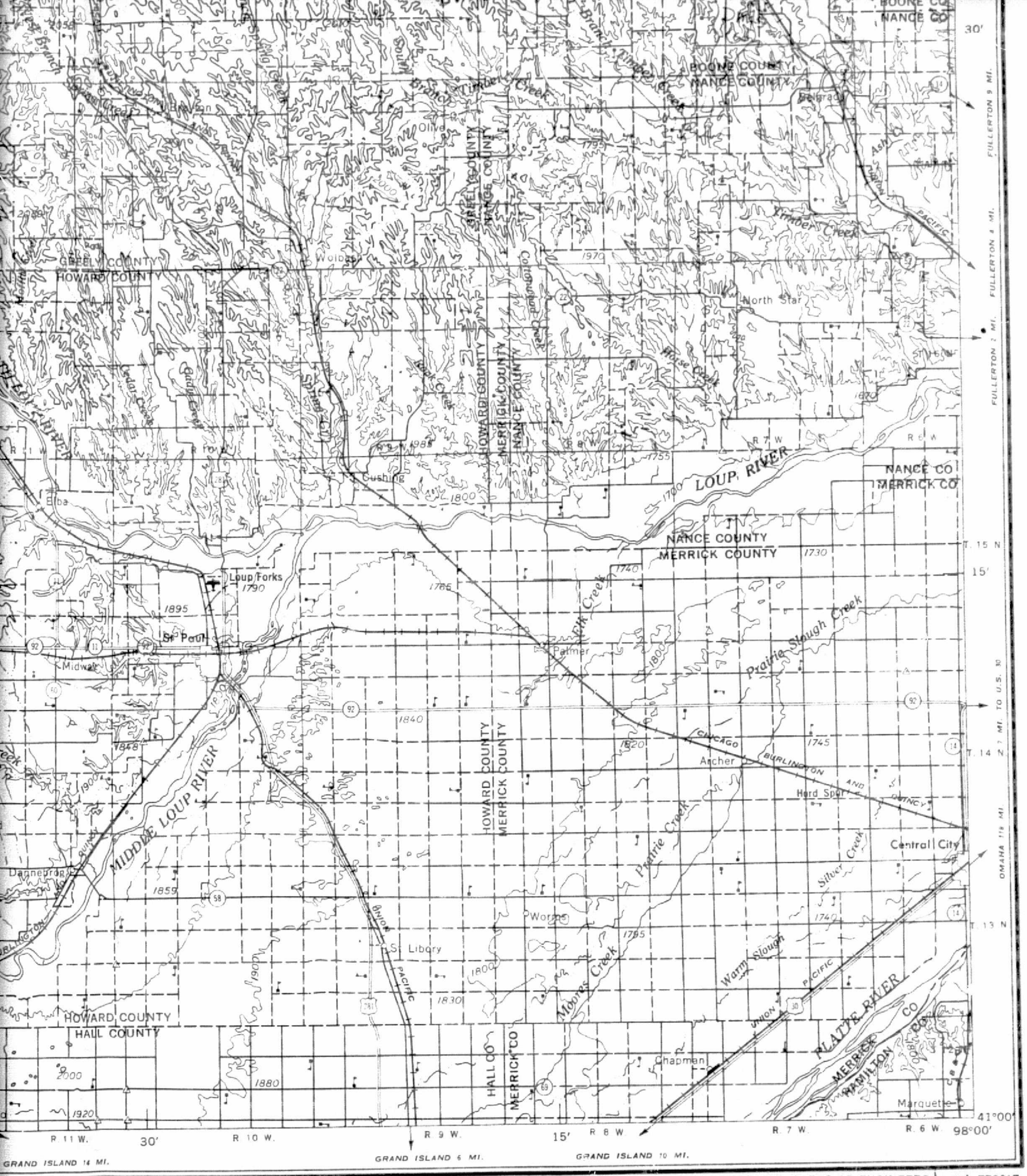
PRINTED BY ARMY MAP SERVICE

5X

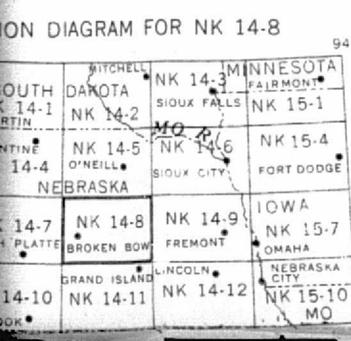
TOWNSHIP OR RANGE LINE

LAND GRANT BOUNDARY

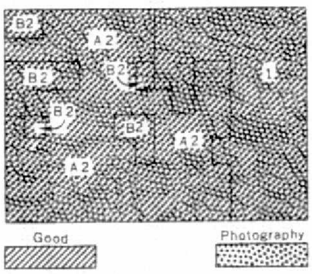
FOLDOUT FRAME 7



PRINTED BY ARMY MAP SERVICE, CORPS OF ENGINEERS, 9-56 776017
SX



RELIABILITY DIAGRAM

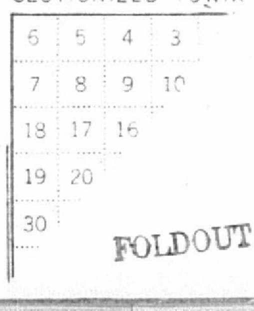


A. Large scale topographic maps, photogrammetric survey, 1951, 1952, 1954.
B. Large scale topographic maps, controlled ground and photogrammetric survey, 1951-52.

TOWNSHIP OR RANGE LINE

LAND GRANT BOUNDARY

SECTIONIZED TOWNS



FOLDOUT FRAME 8

A5.0 MAPPING ILLINOIS GEOLOGY FROM SPACE[1/]

Jerry A. Lineback
Illinois State Geological Survey

A5.1 Geology of central Illinois

Skylab 2 photographs were taken on Pass 7 (Track 33) in a diagonal band across Illinois on 11 June 1973. This band extends from Rock Island to Terre Haute, Indiana. These photographs have been put together in a mosaic and geological interpretations based on S190B color photographs as presented in Figure A5.1, at the same scale as the 2 X enlargements

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Figure A5.1--NEAR HERE

Geologic units shown are:

- c — Cahokia Alluvium, silt, sand, and fine gravel deposited in modern flood plains, often overlies outwash.
- sm — Strip mines, spoil piles and disturbed areas due to coal strip mining and in places to rock quarrying or gravel pits.
- hm — Henry Formation, Mackinaw Member, gravel, sand and silt; glacial outwash deposited along major rivers leading away from the area of Wisconsinan glaciation; also terrace remanents of valley train deposits of this glaciation.
- ec — Equality Formation, Carmi Member, clay and silt; lacustrine deposits in glacial and pro-glacial lakes of Wisconsinan age.
- wt — Wedron Formation, undifferentiated Wisconsinan tills.
- wte — Wedron Formation, tills with morainic topography, elevated, rolling and with better soil drainage.
- gt — Glasford Formation, undifferentiated tills of Illinoian age; includes Vandalia, Radnor, Hulick, and Kellerville Till Members.
- gh — Glasford Formation, Hagarstown Member, gravel, sand and gravelly till in kames and esker-like crevasse filling deposits on the surface of the Illinoian till.

The moraines and other geologic features are labeled, as are the major towns and airports. For orientation, interstate highways are also shown. Several features will be discussed individually.

[1/] Dr. Lineback has published a similar but somewhat more detailed report on the utility of ERTS-1 images and Skylab photographs for mapping geology in Illinois (Lineback, 1975).

FOLDOUT FRAME

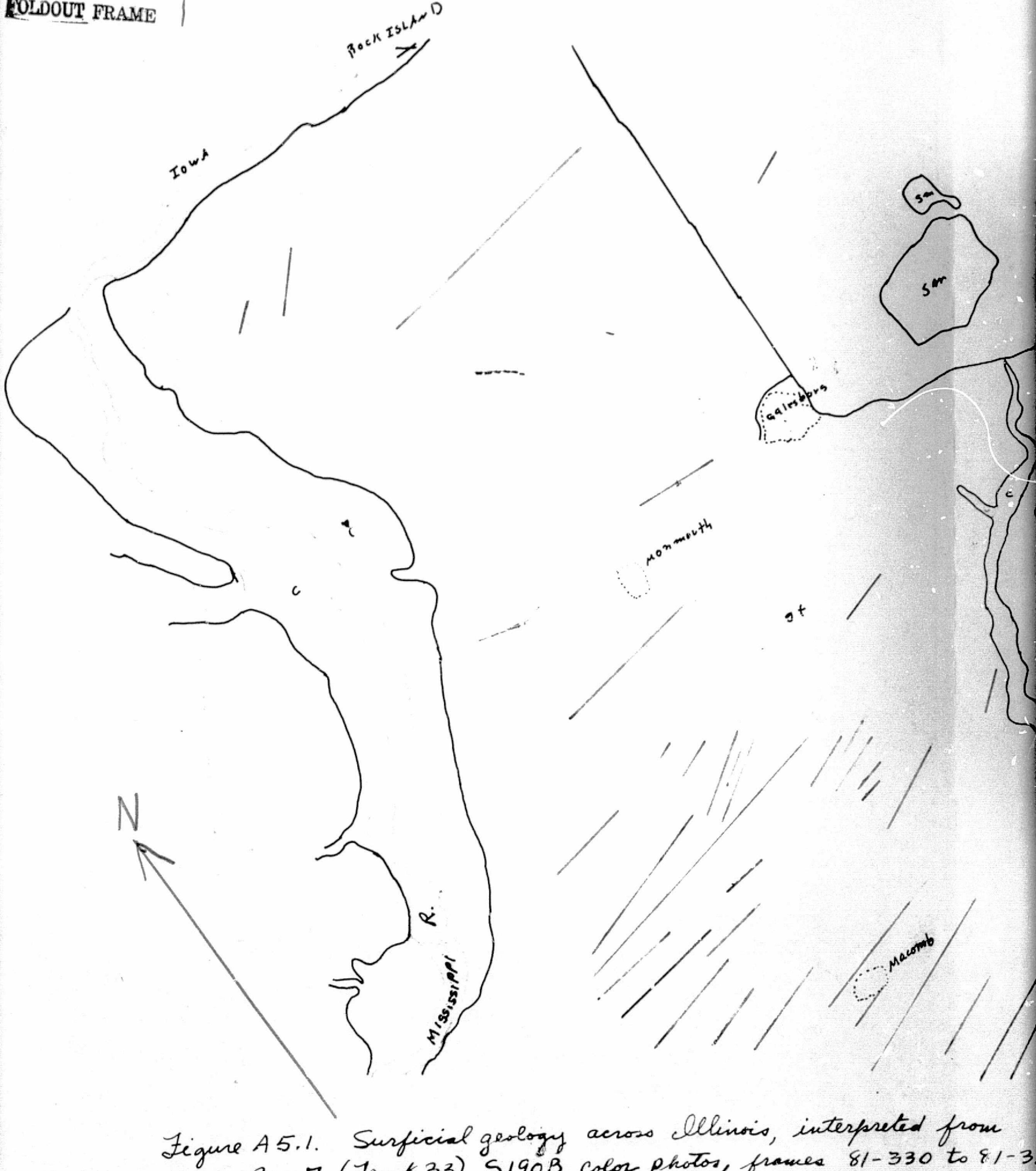
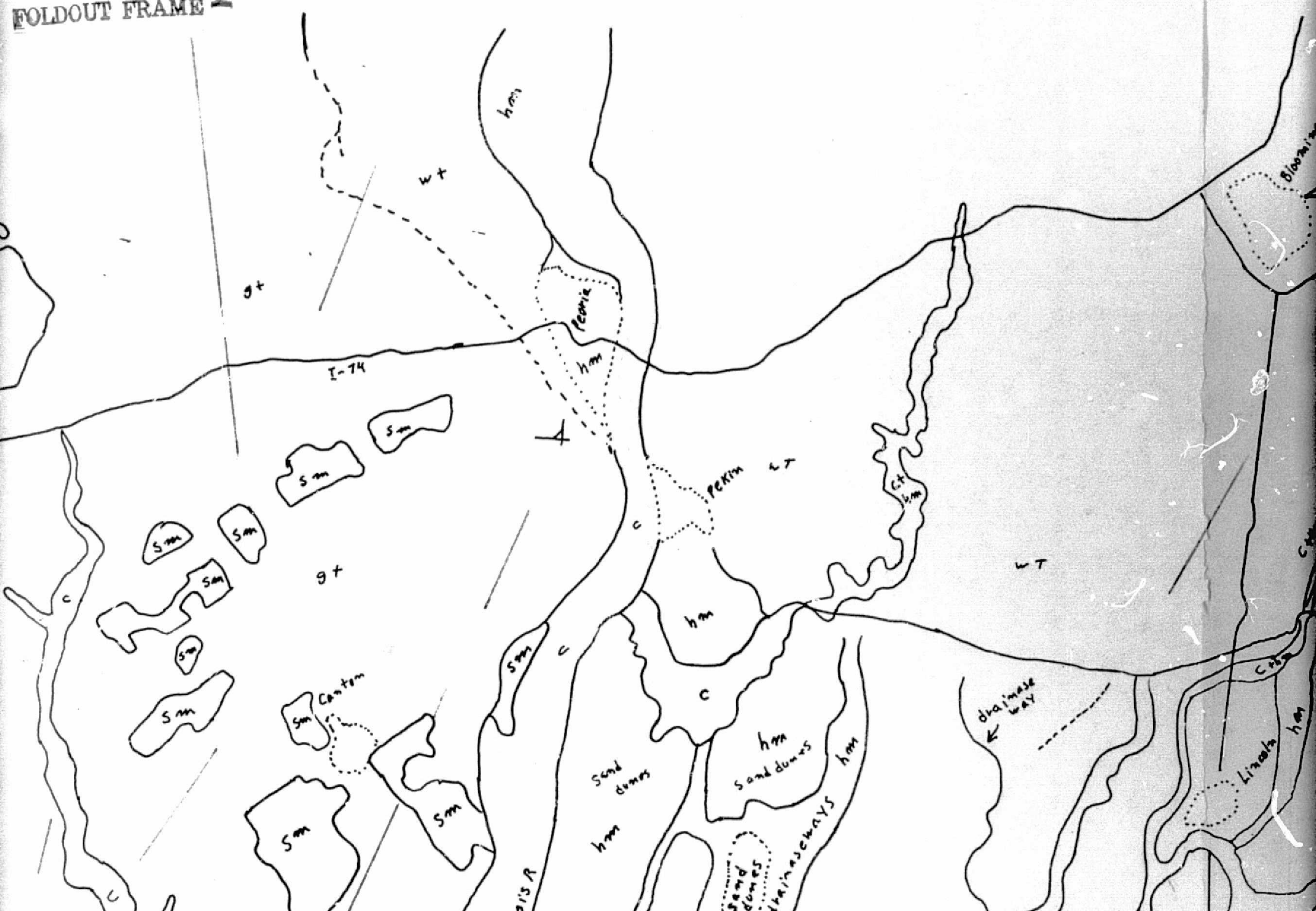


Figure A5.1. Surficial geology across Illinois, interpreted from SL2 Pass 7 (Track 33) S190B color photos, frames 81-330 to 81-3
(Overlay to 2X enlargements to these frames.)



hm
wt
gt
Peoria
I-74
hm
sm
sm
sm
sm
sm
Pekin
wT
c
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c
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c
sm
Canton
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sm
hm
sand dunes
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hm sand dunes
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drainage way
wT
Lincoln
sm
sand dunes
drainageways
hm
Illinois R
c
c
sd + loess
sand dunes
c
sd dunes over hm
surface features
c
c
sm
Spring-field
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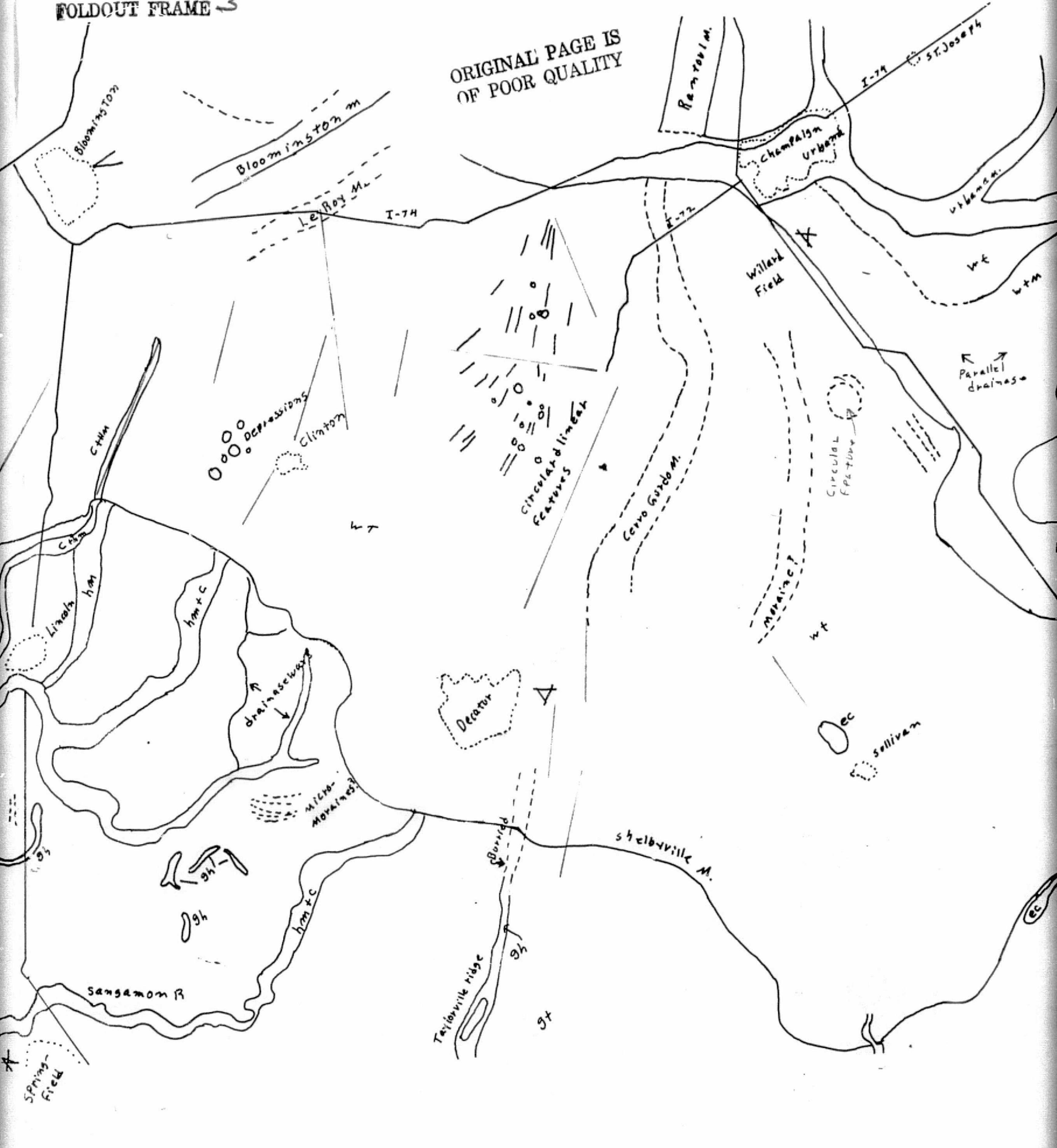
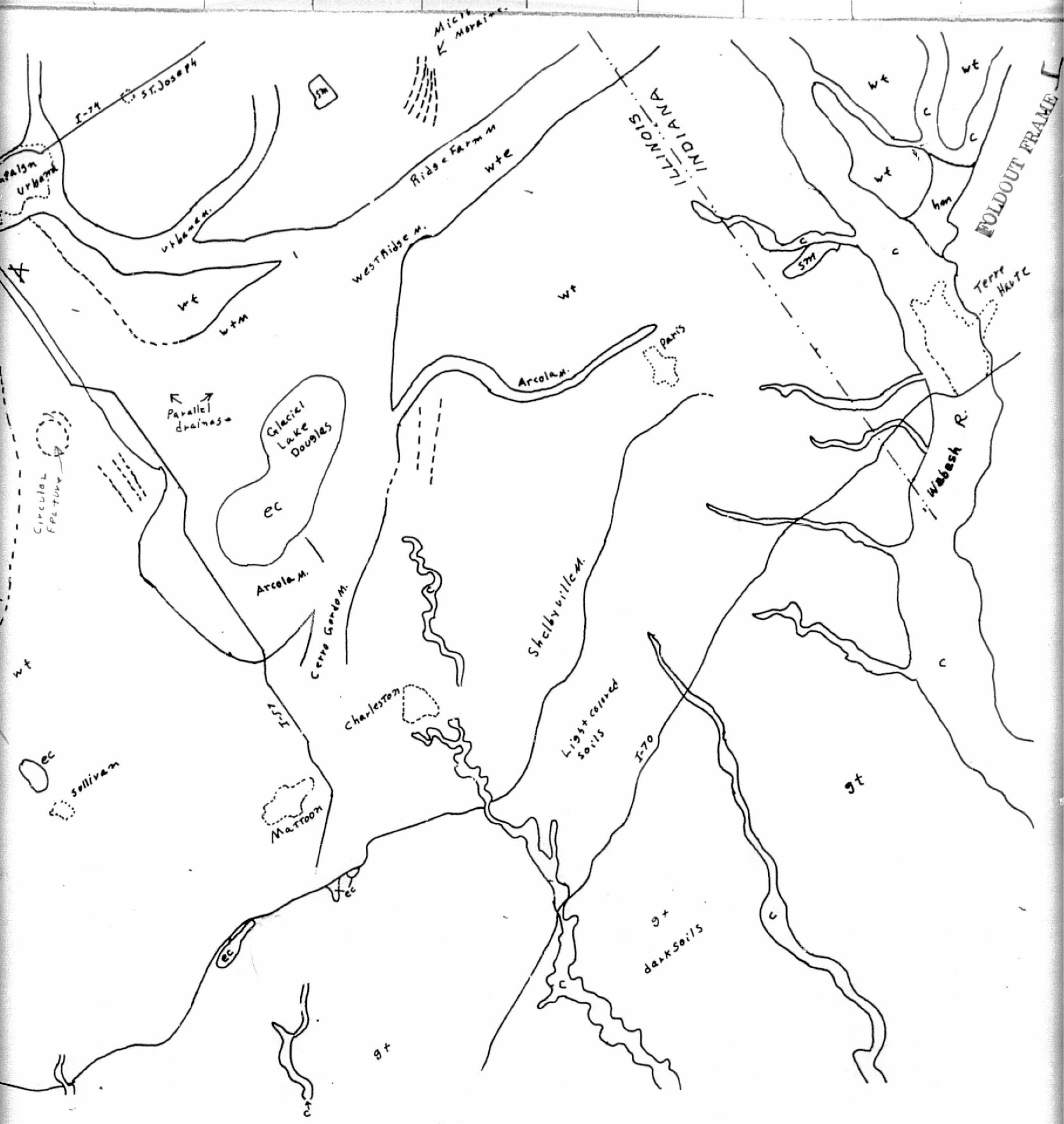
0 5 10 15 20 25 30 Km

rom
o 81-337.

FOLDOUT FRAME 3





I-74
St. Joseph
Urbana
SM
Ridge Farm M.
wte
Urbana M.
West Ridge M.
wt
wtm
ILLINOIS
INDIANA
Arcola M.
Paris
Parallel drainage
Glacial Lake Dougles
ec
Circular Feature
Cerro Gordo M.
Shelbyville M.
Charleston
I-57
Mattoon
Sullivan
Light colored soils
I-70
gt
gt dark soils
c
hm
Terre Haute
Wabash R.

Wisconsinan moraines

Several Wisconsinan "end" moraines appear on the photos and have been labeled. Moraines are not as evident on the S190B photos as on S190A photos, particularly the color IR photos. One possible new moraine extends southwest of Champaign towards Sullivan. The Shelbyville Moraine is marked by a prominent front, but its backside is poorly differentiated.

Surface features of the Wedron tills

Parallel drainage on moraines

Unique fine parallel lines appear on the backside of several moraines in east central Illinois and are not observed elsewhere. They are best developed on the backside of the West Ridge Moraine south of Champaign and on the Arcola Moraine around Glacial Lake Douglas. These features are presently small stream courses which may occupy grooves left by the glaciers.

Micromoraines?

Closely spaced, sub-parallel, curving, and narrow ridges of drift occur southeast and south of Champaign and may represent micromoraines.

Circular and linear features

Circular and linear features, forming a radiating pattern, occur between Champaign and Decatur. This pattern is the surface expression of a sandy till that crops out in this area. This till had been recognized previously, but is unnamed and its surface extent was unknown. The presence of these features permits the mapping of the approximate limits of this till member of the Wedron.

Depressions

Several large depressions are present northwest of Clinton. Why features of this scale are restricted to this one spot is not known. The depressions are filled with dark, poorly drained soils. It is not known if they contain any lacustrine material.

Large circular feature

A large circular feature of unknown origin is reflected in the drainage pattern along the Kaskaskia River south of Champaign and west of I-57.

Glacial lakes

Several glacial lakes have been mapped. The smooth floor of Glacial Lake Douglas stands out in a striking manner. These lake basins contain clay and silt deposits of the Carmi Member of the Quality Formation. Eagle Lake, north of Sullivan, can also be seen. Several small areas of dark, poorly drained soils have been mapped along the front of the Shelbyville Moraine south of Mattoon. These depressions contain thin lake sediments and were probably proglacial lakes at the front of the Shelbyville end moraine.

Alluvium in major valleys and old drainageways

Cahokia Alluvium is mapped in the major valleys. In many of these valleys, the recent alluvium is a thin cover over outwash deposits. Terraces, remanents of the older valley fill, can be recognized only in a few places such as northeast of Terre Haute and north of Peoria. A large area of outwash deposits (hm) occur east of the Illinois River south of Pekin. Sand dunes cover much of the terraces and give them a mottled appearance. The terraces are cut by younger glacial drainageways and by Cahokia Alluvium.

Several wide valleys with presently underfit streams in them can be seen leading away from the Wisconsinan ice margin between Pekin and Decatur. These streams carried outwash and meltwater from the Wisconsinan ice sheet. Several remanent valleys (due to drainage changes) can be identified, particularly east of Lincoln and south of Pekin.

The meander pattern of the rivers in the larger valleys can be easily seen and should make interesting material for a study of stream meanders.

Illinoian drift

Light colored soils occur on Illinoian drift just south of the Shelbyville Moraine with darker soils occurring farther south. The outwash apron of the Shelbyville Moraine is very narrow, so the origin of this difference in soil color is unknown. Thickness of loess and gley deposits is about the same.

Subparallel, narrow, low ridges are present on the surface underlain by the Radnor Till Member of the Glasford Formation. The boundary of the Radnor Till cannot be easily mapped from the S190B Skylab photo.

Ridges of gravelly drift (Hagarstown Member) can be seen at several places. The Taylorville ridge can be seen to extend under the Shelbyville Drift south of Decatur. Smaller ridges are present on the Radnor Till.

Strip mines

Extensive strip mining west of the Illinois River has significantly altered the surface of the area. Areas of active stripping are marked by bare soils, sharply defined spoil piles, and water filled trenches. Recently mined areas are marked by smooth bare soils due to the leveling of spoil piles for reclamation. Vegetated areas indicate reclaimed mines or older unreclaimed mines covered by a natural growth of vegetation. Strip mines are identified by signs of active mining and by dense forest or other vegetation that interrupts normal agricultural patterns.

Linear features

Linear features, shown in red, of a variety of possible origins are present in the area mapped. Those shown generally appear as unusually straight stream segments, although some appear as linear dark or light soil patterns. Bedrock joint patterns are often invoked to explain these linear features. The streams on the Wisconsinan Drift do not generally reach bedrock. The streams in western Illinois are commonly incised into bedrock. Although the exact origin of the linear features is unknown, many of these linears are believed to have their origin in the movement of glaciers. Those in western Illinois follow the general pattern of inferred ice movement and the linear features may have formed as streams, incipient on the deglaciated surface, flowed along grooves formed in the drift by the movement of glaciers.

Skylab 2 S190A

A geologic interpretation of two frames from the S190A multispectral cameras on Skylab has been prepared (Figs. A5.2a and A5.2b). They are from SL2 Pass 7 (Track 33) and cover the area from Champaign to near Rock Island. The S190A frames cover a larger area than the S190B and have lower resolution. However, features needing synoptic overview, such as glacial moraines, show up better on the S190A photographs. The color IR photo is most valuable in mapping soil patterns. The color, and red band black and white, are also useful. The other bands are less useful for geologic mapping.

Figure A5.2a--NEAR HERE
A5.2b--NEAR HERE

Many of the features seen on the S190B photographs can also be seen on the S190A. Strip mines are more difficult to distinguish. Areas underlain by possible lake deposits of Illinoian age north of Springfield are more easily seen. Hills of gravelly Hagarstown Member of the Glasford Formation can be seen south of Decatur. Additional units mapped on this series of photographs include pe = Peoria Loess; pl = Parkland Sand (dunes); gv = Glasford Formation, Vandalia Till Member; gh/k = Glasford Formation, Hulick and Kellerville Till Members; and br = bedrock.

A small area of dark soil on a upland surface marks the Glasford disturbance, a bedrock cryptovolcanic structure. This domal bedrock structure is now used as a gas-storage pool.

The border of the Radnor Till (gr) can roughly be distinguished on the S190A color IR photograph. The Teneriffe Silt (t) a pro-Radnor Lake deposit occurs north of Springfield and shows as dark colored soils. The dashed line north of Decatur marks the boundary between the unnamed till member of the Wedron Formation, with the circular and linear features on its surface, and the Tiskilwa-Delevan Till members to the west.

A5.2 Geology of southern Illinois

One S190B frame (SL2-81-192, Pass 6, Track 19) taken over extreme southern Illinois was selected for interpretation (Fig. A5.3). The following map units were determined.

Figure A5.3--NEAR HERE

Figure 13.2a. Surficial geology of East-Central Illinois. Overlay is 4x enlargement of SL2 Pass 7 S190A color-infrared frame 9-254. See text for explanation of geologic symbols.

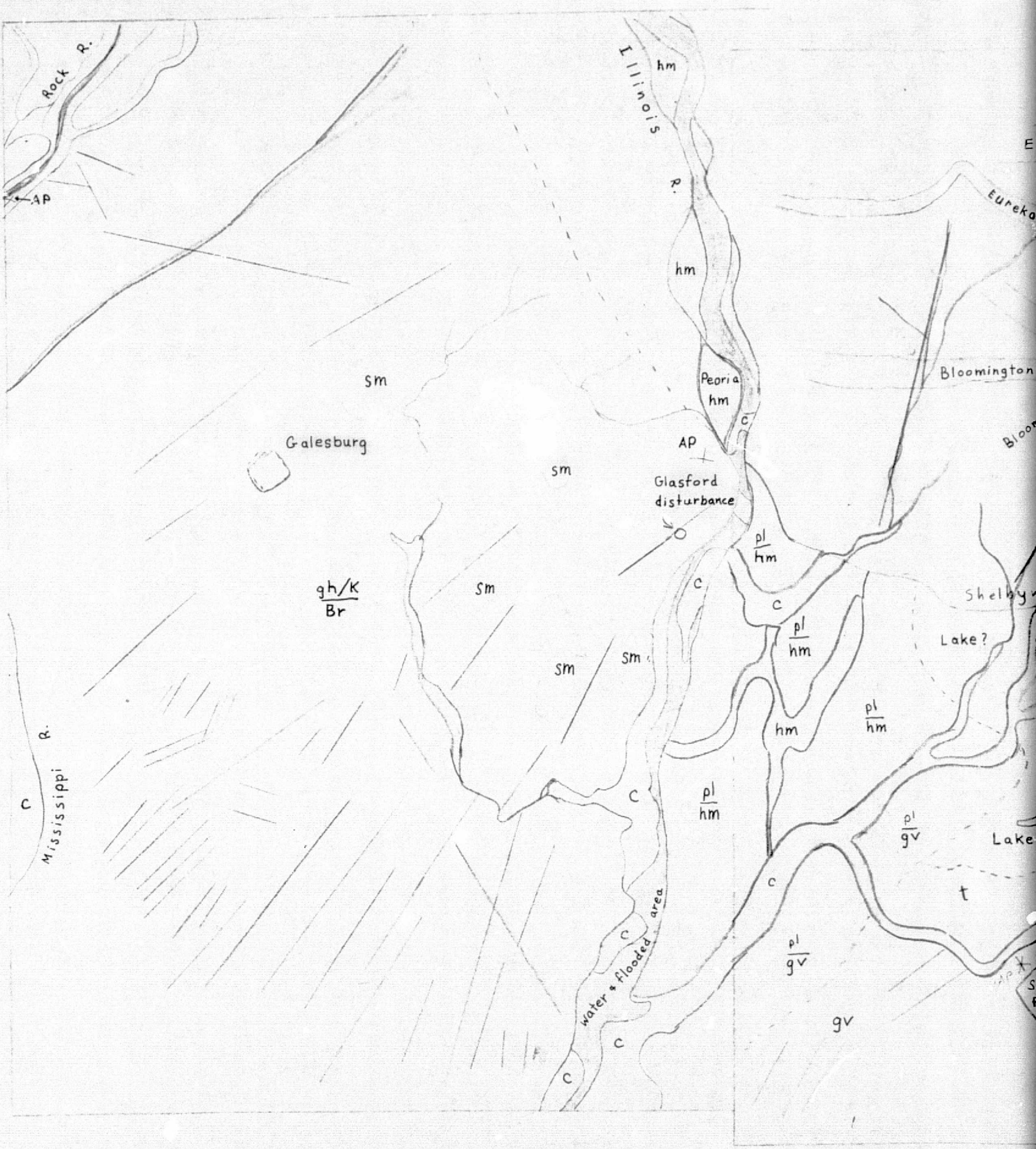
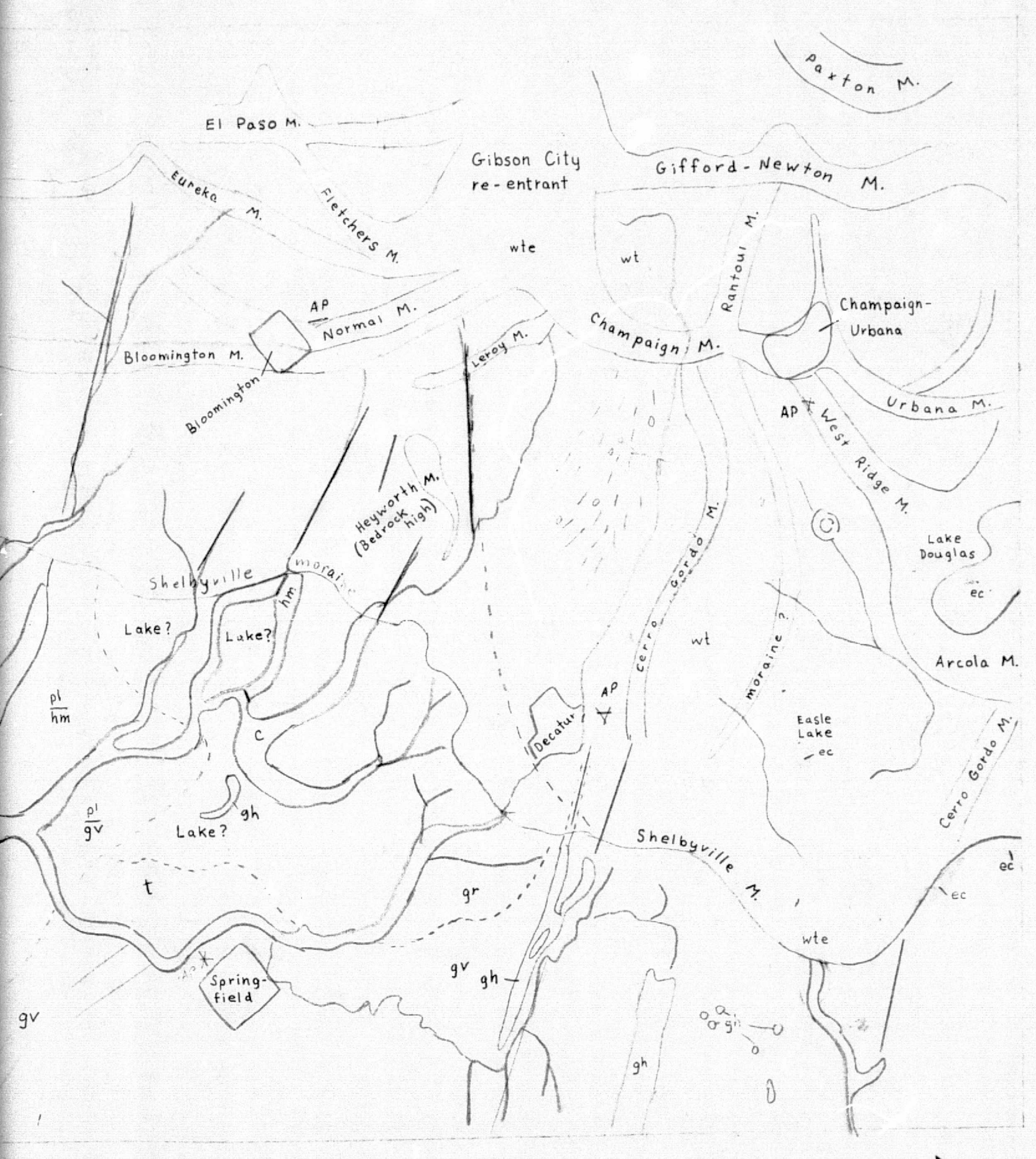


Figure A5.2b. Surficial geology of central Illinois, interpreted from SL2 Pass 7 S190A color-infrared frames 9-252 to 9-254.

See text for ex

DRAINAGEWAYS



See text for explanation of geologic symbols.

Scale

20 Km

N

DRAINAGEWAYS

LINEATIONS

AP - AIRPORT

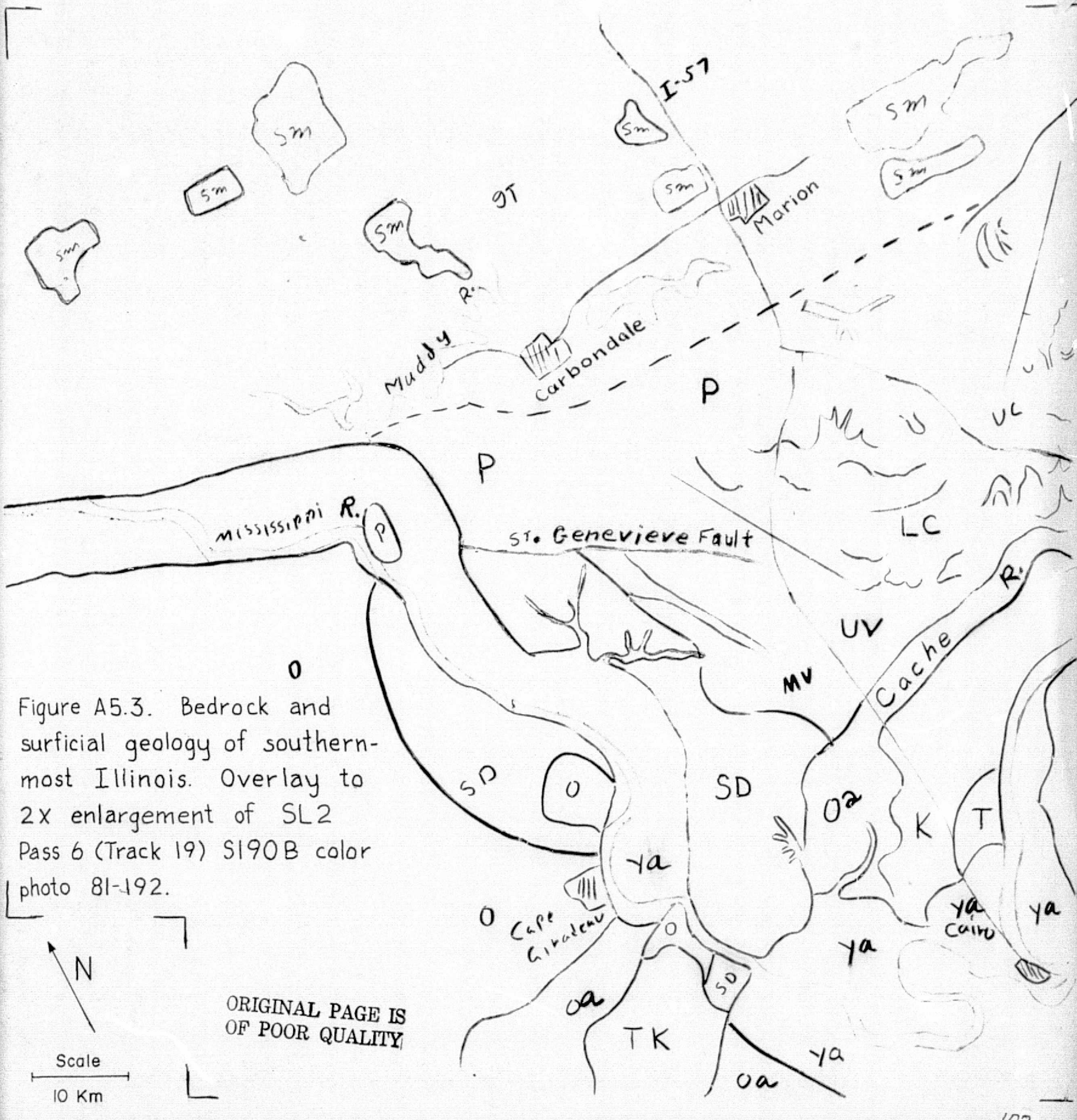


Figure A5.3. Bedrock and surficial geology of southernmost Illinois. Overlay to 2X enlargement of SL2 Pass 6 (Track 19) S190B color photo 81-192.

ya - Younger alluvium (Cahokia), present flood plains, many meander scars.

oa - Older alluvium (Cahokia) in cut-off channels of the Mississippi and Ohio Rivers (Cache River, for example).

gt - Glasford Formation, till of Illinoian age.

TK - Tertiary-Cretaceous, partly marine.

T - Tertiary, silt and clay.

K - Cretaceous, silt and clay.

P - Pennsylvanian, shale and sandstone.

UC - Upper Chester, shale, sandstone, and limestone.

LC - Lower Chester, shale, sandstone, and limestone.

UV - Upper Valmeyeran (Mississippian), St. Louis and Ste. Genevieve Limestones.

MV - Middle Valmeyeran (Mississippian), Ullin and Salem Limestones.

SD - Silurian and Devonian, mostly siliceous limestones.

O - Ordovician, limestones.

The flow patterns of the Mississippi and Ohio Rivers is well shown. The Thebes Gorge, where the Mississippi River cuts across a bedrock high, is well shown. Land use patterns permit distinguishing the siliceous Silurian and Devonian rocks from areas underlain by limestones of the Ordovician and Mississippian. Discontinuous lines indicate outcrops of Chesteran and Pennsylvanian limestones and sandstones. The Ste. Genevieve fault and a couple of other faults show as linears. The glacial boundary, dashed line south of Carbondale, marks the boundary between agricultural flatlands and the forested uplands formed by the outcropping of Pennsylvanian sandstone. An unexplained semicircular feature is present north of the fault along the east side of the photo. Strip mined areas can be mapped, but some older "reclaimed" areas may have been missed.

A5.3 ERTS images and Skylab photographs for geologic mapping

ERTS images generally provide insufficient resolution for detailed geologic mapping. Linears, major drainage patterns, some glacial moraines, and some large scale features can be mapped. Skylab photographs provide good resolution while providing the synoptic overview so valuable to geologic mapping. Many significant surficial geologic features can be seen and mapped. Skylab photographs can be used directly in preparing geologic maps of an area or used as an aid in compiling geology from many sources. S190B photographs provide the best resolution, but certain features can be seen better on the color IR photographs taken by the S190A camera.

Skylab photos cover only a portion of Illinois on a one-time basis. ERTS images are repetitive and many images for the same area can be accumulated. For example, 20 ERTS images have been found that show sediment plumes in Lake Michigan for a study of lake currents. ERTS images are valuable for studying dynamic geologic problems such as the currents in Lake Michigan.

All space images for geologic purposes are season dependent. The best photos for mapping surface features have been taken in the spring, after the ground has been planted and before corn and soybeans have grown much. The most significant results have come in the period of March to June. ERTS images can be computer processed to enhance certain features, but at present this has limited application to geologic mapping.

A5.4 Conventional geologic map from Skylab photos

Figure A5.4 is an overlay to and interpreted from a 2 X enlargement of SL2 Pass 7 (Track 33) S190B color photo 81-366. It is a conventional surficial-geology map. My knowledge of the geology of the area was used to prepare the map. The units shown are:

Figure A5.4--NEAR HERE

wb - Wedron Formation, Batestown Till Member

wbe - Batestown in the form of end moraines

wu - Wedron Formation, unnamed member, till with circular and linear features on its surface

wg - Wedron Formation, Glenburn Till Member

wge - Wedron Formation, Glenburn Till Member in end moraines

ed - Equality Formation, Dolton Member, deltaic deposits prograding into Glacial Lake Douglas

ec - Equality Formation, Carmi Member, lake deposits in various glacial lakes

gv - Glasford Formation, Vandalia Till Member

c - Cahokia Alluvium

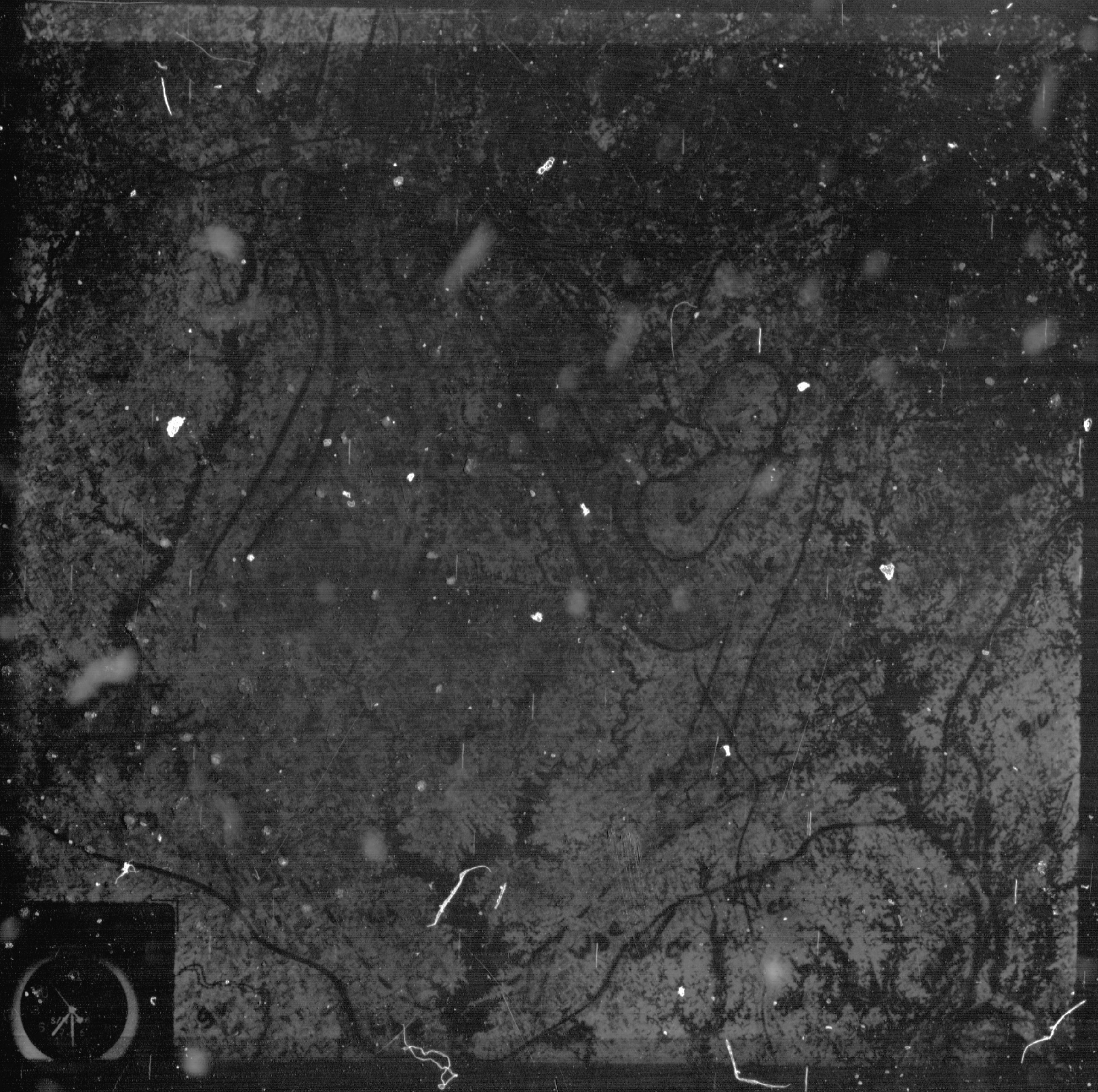


Figure A5.4. Conventional surficial geologic map of part of the area shown in Fig. 5.1. Overlay to 2x enlargement of SL2 Pass 7 S190B color photo 81-336.

A6.0 ANCILLARY STUDIES OF GEOLOGIC LINEARS INTERPRETED FROM SKYLAB PHOTOS

Roger B. Morrison and Richard K. Rinkenberger

A6.1 Introduction

Ancillary to the main objectives of the project, geologic linears were mapped in a few parts of the Great Plains-Midwest. Detecting and mapping geologic linears from space images is a new, important preliminary step in developing knowledge about the tectonic pattern (and certain details of the erosional history), even in so structurally stable a region as the Great Plains-Midwest. Establishing the validity and origin of all the detectable geologic linears, however, will require much additional ground and subsurface exploration, involving many man-years of effort. The preliminary mapping of the linears can point to strategic places for making these additional studies. Thorough analysis of the geologic linears holds great promise of contributing significantly to the knowledge of details of structure and stratigraphy of bedrock and surficial units in this region, especially in areas lacking extensive exposures and detailed data on subsurface stratigraphy. Such an analysis has important application to exploration and development of resources of petroleum, coal, ground water, and other minerals.

In its widest, non-genetic sense, the term "geologic linear" is used here for any linear feature, straight or curved, that likely is of geologic or geomorphologic origin. Several types of geologic linears are visible on SL photos of the areas studied in the Great Plains-Midwest: (1) those that reflect known or possible faults or large joints, (2) those due to wind scour (deflation) and/or deposition, (3) those caused by glacial erosion and/or deposition, and (4) those of indeterminate origin. Linears caused by faults and joints are indicated by straight or slightly curved valleys or escarpments, and/or by tonal differences (indicating soil or vegetation differences)--either bands lighter or darker than background, or lighter on one side than the other. Such linears (visible on SL photos) range in length from tens of miles to less than a mile. Wind-scour linears are common in parts of the northeastern Nebraska study area, where they generally occur as groups of parallel ridges and furrows, invariably alined northwest-southeast, generally having less than 20 m of local relief, and ranging in length from several miles to less than a mile. (In the Broken Bow quadrangle, which extends into the eastern edge of the Sand Hills of Nebraska, some areas of sand dunes show subparallel alinement of dune crests and inter-dune depressions--but linears of this type were not mapped.) Glacial linears are present in places on the Illinoian drift plain of western Illinois. They are low, subparallel drumlinoid ridges, alined northwest-southeast and mostly less than 20 m high. They are evident mainly from differences in soil color/tone or in land use.

In the northeastern Nebraska study area, Morrison mapped on a conservative basis the geologic linears that were clearly identifiable by stereoscopic viewing with a Kern PG-2 stereoplotter or an Old Delft stereoscope (Figs. A4.2 and A4.3). In the Illinois study area, Lineback similarly mapped several types of geologic linears (Figs. A5.1 to A5.4). However, more intensive analysis and mapping, specifically for all possible geologic linears, was done by Rinkenberger on two different S190A frames. One frame covers part of northeastern Missouri and a small part of western Illinois (Fig. A6.1), the other covers the vicinity of Omaha, Nebraska (Fig. A6.2).

A6.2 Criteria used for identifying geologic linears

The following types of criteria were used for identifying and mapping the geologic linears:

1. valley alinements (straight or curved);

2. ridge crests;

3. soil changes as evidenced by color, CIR, or B/W tonal changes;

4. certain persistent and sharp changes in topography; e.g., tops or bottoms of escarpments; marked changes in patterns of relief and dissection of uplands;

5. alined changes in vegetation clearly not primarily caused by land-use features such as field and pasture boundaries;

6. combinations of the above.

Care was taken to eliminate (not map) cultural linears such as highways, railroads, and agricultural boundaries, as well as spurious features such as contrails of jet planes (and their shadows) and boundaries of areas wetted by local rainstorms. Assisting this elimination was the control provided by topographic maps, highway maps, repetitive SL flights over the same area, and ultrahigh airphotos.

Commonly the linears are indicated by differences in color (hue, chroma, and value on color and CIR photos) or tone (on the B/W photos), which reveal one or more of the criteria listed above. Thus, some linears are lighter toned, others darker, than background; others are variegated along their course, still others are manifested by lighter tones on one side of the boundary on which they are drawn. Some geologic linears show clearly, others are indistinct.

A6.3 Methods of examination

The geologic linears mapped in the northeastern Nebraska and Illinois study areas (Figs. A4.2, A4.3, A5.1, A5.2, A5.3) were detected in the course of mapping analytic geomorphology or surficial geology by the methods described in sections 7.2, 7.3, A4.3, A5.1 and A5.2. The chief means of examination were magnifying stereoscopes and (for the Broken Bow quadrangle, Nebraska) a Kern PG-2 stereoplotter.

In the more intensive studies made by Rinkenberger specifically for geologic linears, the SL photos were examined in the following ways:

1. (The chief method.) Inspection of 4X transparency enlargements of various S190A spectral bands, by naked eye (without a stereoscope or magnifier) on a light table. The linears were mapped on transparent overlays to the photos. Each transparency was viewed: (a) from different angles (vertical to highly oblique), (b) with different

intensities of backlighting, (c) at different directions to the line of sight, (d) at various distances from very close to 6 feet, and (e) under a reducing glass.

2. Similar viewing of 2X enlarged transparencies of S190B color photos.

3. Method (1), reinforced by superposing a transparency of another spectral band of the same S190A frame (e.g., B/W red band with B/W green band), and slightly shifting the two transparencies in relation to each other, in various directions, to obtain linear edge enhancement.

4. Like above, but combining transparencies from different SL flights (but, of course, covering at least parts of the same scene). Because of small scale differences in the photos, commonly slight adjustments were needed to register each quadrant or so of the basic scene.

5. Viewing by methods (1) and (3), but using diazo transparency copies in 5 colors (brown, red, magenta, green, and blue) of each band of the 4X S190A transparencies--i.e., viewing the diazo color transparencies both singly or in superposed combinations of different bands of the same frame, with the different bands in different colors in various combinations.

6. Viewing <u>negative</u> transparency 4X S190A enlargements by methods (1) and (3).

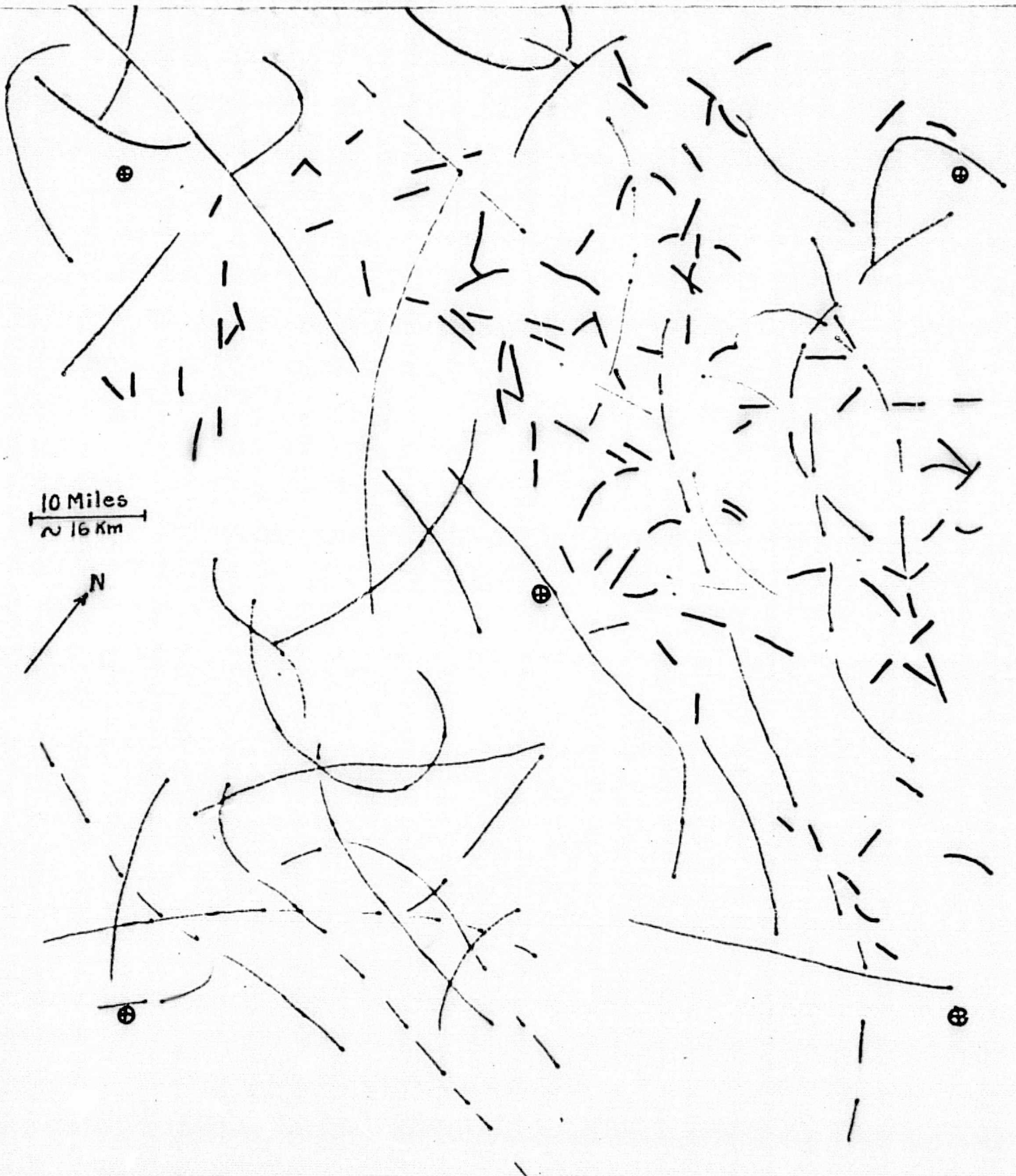
7. Viewing 4X transparency S190A or 2X S190B enlargements under 1.5 and 4.5X enlargement by an Old Delft stereoscope.

In the NE Missouri-western Illinois study area (Fig. A6.1), the linear study was confined to one S190A frame: SL4 Pass 82 (Track 1) frame 290 (magazine/roll nos. 61-66). All the geologic linears distinguished on different S190A bands of this frame were plotted on a single overlay to the 4X enlarged scene (Fig. A6.1). Most of the linears were detected from the B/W red and B/W green-band transparencies of this winter scene, which is entirely snow-covered except the woodlands. A few additional linears were added from examination of S190A 4X transparencies, covering most or parts of this scene, from SL flights at different times of year. No distinction was made between sharply defined and subtle linears, nor between the various criteria by which the linears were distinguished.

Figure A6.1--NEAR HERE

In the Omaha and environs study area, mapping of the geologic linears was confined to another single S190A frame from SL2 Pass 6. Four separate overlays were prepared, one for 4X transparency enlargements of each of the following photos of this frame: color 10-133, CIR 9-133, B/W IR 8-125, and B/W red 11-125 (Fig. 6.2 a, b, c, d). Also, the degree of prominence of the linears was distinguished; the very prominent ones are shown by lines of alternating very long and short dashes, the prominent ones by solid lines, and the least prominent by short-dashed lines. In addition, colors were used to show the type of criteria by which the linears were identified: green was used for definite valley alignments; red for tonal bands, either lighter or darker than background;

Figure A6.1. Geologic linears in northeastern Illinois-western Illinois, interpreted mainly from all S190A bands (as a composite) from SL4 Pass 82 (Track 1) frame 290. Lighter lines are the more important linears, black lines are minor linears. ⊕ = registry marks for photo 65-290.



and blue for boundaries between light- and dark-toned areas. (Red is combined with green where a valley alinement is combined with or alternates with a tonal band.)

Figure A6.2--NEAR HERE

A6.4 Conclusions from Rinkenberger's intensive analysis

On both study areas, viewing method (1) yielded most of the linears distinguished--i.e., viewing the transparency enlargements on a light table without magnification and non-stereoscopically. Viewing through a reducing glass commonly sharpened the definition of the more subtle (but relatively long) linears. Viewing under magnification, preferably stereoscopic, occasionally enabled a few more of the shorter linears to be identified--but the more prominent and longer linears generally were less visible than with the naked eye or a reducing glass. However, magnification up to 10X did aid in distinguishing cultural linears (e.g., highways) from geologic ones.

Viewing the 2X S190B color transparencies (method 2) generally enabled only a few more of the smaller linears to be distinguished than were identified by method 1. Also, the S190B photos are only one band (color, in these study areas) and thus lack the advantages of using viewing methods (3) and (5). However, they provide control for recognizing (and eliminating) cultural linears, because of their superior resolution.

Winter snow-covered scenes proved better than late-spring or summer ones for identifying most linears, mainly because of less vegetational "noise" due to differences in agricultural land use and in natural vegetation, but also because differences in soil-drainage are minimized. Snow-covered B/W red and B/W green-band scenes were the most useful of all.

Short and Lohman (1973, p. 14) commented on the effect of sun-illumination direction in shadow enhancement of linears of various orientations; they observe that NE-SW linears are enhanced in space images, but NW-SE linears commonly are almost invisible. Our observations from SL photos do not entirely support this conclusion: NW-SE linears commonly are as distinct as NE-SW ones. This may be because shadow enhancement commonly is negligible in the SL photos, because the photos generally were taken when the sun was near its zenith.

A6.5 Comparison with results from analysis of Landsat (ERTS)-1 images

Landsat-1 multispectral images have proved better than Skylab photos for detecting major linears, especially those likely of tectonic origin. This is because the moderate resolution of the Landsat images reduces extraneous "noise"; also the repetitive coverage provides many more images, taken at various times of year, with various conditions of soil-moisture and vegetative cover. However, the smaller linears cannot be detected on the Landsat-1 images.

SL photos, on the other hand, are superior for detecting the intermediate and minor linears. For example, minor wind-scour and drumlinoid linears cannot

Figure A6.2, part A. Geologic linears in the vicinity of Omaha, Nebraska, plotted on 4 X enlargements of various S190A bands of the same scene (frame) from SL2 Pass 6 (Track 19). This part of the figure is from the color "band" (0.4-0.7 µm), frame 10-133.
⊕ = registry marks on the photo.

Figure A6.2, part B. Geologic linears in the vicinity of Omaha, Nebraska, plotted on 4 X enlargements of various S190A bands of the same scene (frame) from SL2 Pass 6 (Track 19). This part of the figure is from the color-infrared band (0.5 - 0.88 µm), frame 9-133.
⊕ = registry marks to the photo.

Figure A6.2, part C. Geologic linears in the vicinity of Omaha, Nebraska, plotted on 4 X enlargements of various S190A bands of the same scene (frame) from SL2 Pass 6 (Track 19). This part of the figure is from the B/W red band (0.6-0.7 µm), frame 11-125.
⊕ = registry marks on the photo.

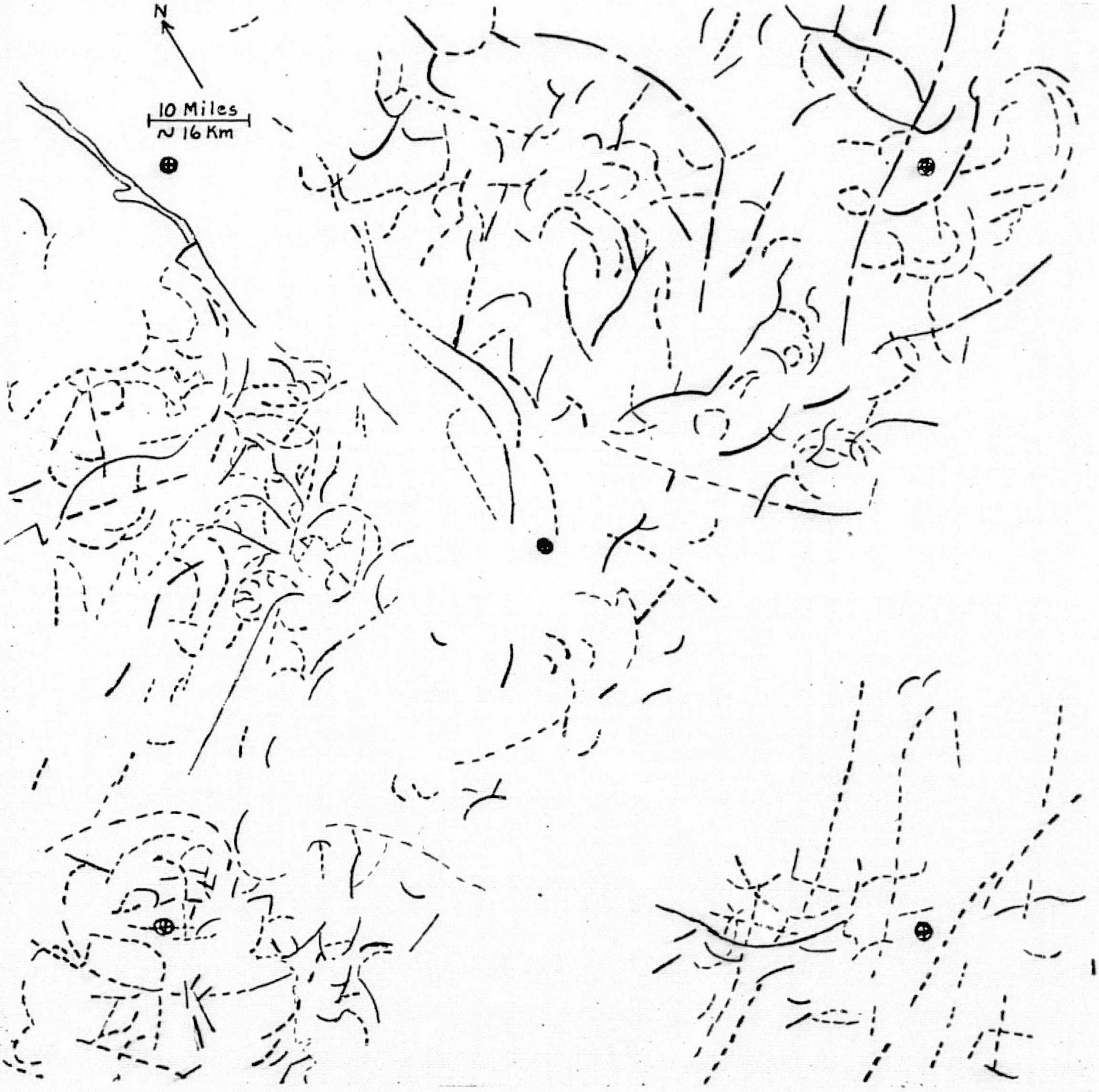


Figure A6.2, part D. Geologic linears in the vicinity of Omaha, Nebraska, plotted on 4 X enlargements of various S190A bands of the same scene (frame) from SL2 Pass 6 (track 19). This part of the figure is from the B/W "farther" near-infrared band (0.8-0.9 µm), frame 8-125. ⊕ = registry marks on the photo.

be seen on Landsat-1 images whereas they are clearly evident on the better SL photos. Thus, a worthwhile "zoom effect" can be obtained by first analyzing Landsat-1 images, then SL S190A photos, then SL S190B photos, and possibly then ultrahigh airphotos and conventional airphotos.

A6.6 General conclusions

The synoptic, fairly high-resolution overviews of large regions provided by SL photos are superb tools for identifying geologic linears, particularly if these photos are used in combination with Landsat MSS images. Our attempts to use the SL photos to map geologic linears in a few parts of the Great Plains-Midwest (together with the earlier effort over much larger parts of this region, using Landsat-1 MSS images) have shown these linears to be much more numerous than previously was suspected. The better resolution of SL photos compared with Landsat MSS images enables distinguishing minor linears that are invisible on the Landsat images, and also commonly permits identifying the probable origin of the linears. For example, many linears likely caused by faults or joints can be distinguished from wind-scour and glacial linears. However, a large percentage of the possible geologic linears (determined from intensive analysis such as Rinkenberger's) can be identified only vaguely; moreover, the origin of at least as large a percentage of the total geologic linears cannot be determined by interpretation of SL photos. As pointed out in the Introduction to this chapter, many man-years of effort, involving both surface and subsurface exploration, will be required to establish the nature of all the detectable geologic linears. Mapping the linears from space images and airphotos can point to strategic places for making the additional studies.

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